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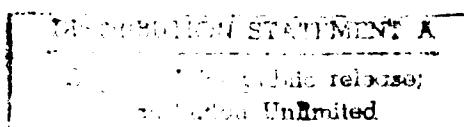
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The VISION Assessment System

Class IX Sustainment Planning

Christopher L. Tsai, Robert S. Tripp,
Morton B. Berman



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United States Army



Assessment For	
Class IX	<input checked="" type="checkbox"/>
Class X	<input type="checkbox"/>
Development	<input type="checkbox"/>
Surveillance	<input type="checkbox"/>
P-1	
Distribution/	
Availability Codes	
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Dist	Special
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PREFACE

This report describes the VISION Assessment System (VAS), a decision support system designed to help planners evaluate and enhance equipment sustainability throughout the Army. It is the second in a series of VISION documents outlining concepts for improving operational effectiveness through better logistics decisionmaking in the Class IX (i.e., spare parts) arena. The first VISION report described a decision support system for prioritizing Class IX repair and distribution. It was renamed by the Army and is now known as the Readiness-Based Maintenance System (RBMS).¹

VISION—for Visibility of Support Options—comprises three related decision support systems for Class IX management: VAS, RBMS, and a third system (still in an early conceptual stage) aimed at such logistics command and control (C2) issues as the interface between operations planning and logistics planning and the passage of information among different units and echelons within the logistics system.

All three components of VISION share a common goal of increasing combat capability and/or reducing support costs through the use of advanced logistics management information and decision support systems. In addition, they emphasize three major themes: the use of operationally relevant measures of performance, such as weapon system availability and the likelihood of achieving commander-specified availability goals; the need to explicitly recognize uncertainty and the value of management adaptation in counteracting the effects of unanticipated events; and the need to develop an integrated view across the many echelons and functions within the Army's complex support system. VISION complements ongoing Army initiatives to modernize Standard Army Management Information Systems (STAMISes). VAS, RBMS, and the VISION C2 System all offer a means for synthesizing a wide variety of data and taking advantage of gains in data quality and timeliness.

VAS focuses in particular on three questions of fundamental importance to sustainment planners: Can the logistics system support operational needs and objectives? If not, what are the impediments likely to be? And what can be done *beforehand* to avoid or mitigate

¹See R. S. Tripp, M. B. Berman, and C. L. Tsai, *The Concept of Operations for a U.S. Army Combat-Oriented Logistics Execution System with VISION (Visibility of Support Options)*, RAND, R-3702-A, March 1990.

potential problems? VAS is intended to be a broadly applicable tool with users and uses ranging from division level to the national level. This report explains the underlying motivation and essential elements of the VAS concept. It explores the range of VAS applications and describes its principal operating mechanisms. It concludes by identifying issues for further research and proposing the development of prototypes to answer remaining questions.

The research reported here was performed in the Military Logistics Program of RAND's Arroyo Center. It is part of a project entitled "Logistics Management System Concepts to Improve Weapon System Combat Capability." This project is jointly sponsored by the Assistant Deputy for Materiel Readiness of Army Materiel Command (AMC), the Commanding General of the Combined Arms Support Command (CASCOM), and the Director of the Strategic Logistics Agency (SLA). This research should be of particular interest to logistics planners and information systems developers at both the field user and national levels. It may be of general interest to the wider Army logistics community and to sustainment planners in other services, in the Office of the Secretary of Defense (OSD), and on the Joint Staff.

THE ARROYO CENTER

The Arroyo Center is the U.S. Army's federally funded research and development center (FFRDC) for studies and analysis operated by RAND. The Arroyo Center provides the Army with objective, independent analytic research on major policy and organizational concerns, emphasizing mid- and long-term problems. Its research is carried out in four programs: Strategy and Doctrine; Force Development and Technology; Military Logistics; and Manpower and Training.

Army Regulation 5-21 contains basic policy for the conduct of the Arroyo Center. The Army provides continuing guidance and oversight through the Arroyo Center Policy Committee (ACPC), which is co-chaired by the Vice Chief of Staff and by the Assistant Secretary for Research, Development, and Acquisition. Arroyo Center work is performed under contract MDA903-91-C-0006.

The Arroyo Center is housed in RAND's Army Research Division. RAND is a private, nonprofit institution that conducts analytic research on a wide range of public policy matters affecting the nation's security and welfare.

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SUMMARY

This report describes the underlying motivation, characteristics, and possible applications of the VISION Assessment System (VAS).¹ VAS is a decision support system designed to improve the ability of Army logisticians to answer three questions that are fundamental to Class IX (i.e., spare parts) sustainment planning:

- Can the logistics system support operational needs and objectives throughout the course of a planned conflict?
- If not, where and when are problems most likely to emerge, and how serious are they likely to be?
- What can be done *beforehand* to avoid or mitigate those potential problems?

VAS recognizes many of the complications presented by such factors as uncertainty and the complexity of the logistics system, and it contains features for dealing with them.

THE NEED FOR ENHANCED SUSTAINABILITY ASSESSMENT

Although the changing world environment has raised considerable doubt about the future shape and direction of the U.S. Army, the critical importance of combat sustainment remains undiminished. The key role of *anticipation* in logistics doctrine continues to underscore the need for effective *planning*.² In turn, planning depends upon worthwhile *assessment* tools that can help planners evaluate both current sustainability and the potential benefits and liabilities of alternative support concepts.

Despite the significance of sustainment planning and assessment, the Army has developed few systematic methods for directly addressing

¹VISION—for Visibility of Support Options—is an integrated series of decision support systems aimed at increasing combat capability and/or reducing support costs through the use of advanced information systems and management techniques. VAS is one of its three major elements. Appendix A gives an overview of VISION.

²Anticipation is one of five "sustainment imperatives" found in both AirLand Battle (ALB) and AirLand Battle-Future (ALB-F) doctrine. See, respectively, FM 100-5, *Operations*, Headquarters, Department of the Army, Washington, D.C., May 1986; and GEN J. W. Foss, "AirLand Battle-Future," *Army*, February 1991, pp. 20-37.

the three questions listed above. Related tools that might be turned to this purpose typically suffer from at least one or two of the following limitations:

- Emphasis on readiness at the expense of sustainability
- Limited wartime and weapon system orientation
- Emphasis on supply problems and solutions at the expense of other functions (e.g., maintenance and transportation)
- Emphasis on requirements at the expense of assessment
- Limited attention to uncertainty and the potential role of management adaptation.

Army planners need a tool that is specifically aimed at sustainability assessment and that overcomes these limitations.

THE VISION ASSESSMENT SYSTEM CONCEPT

VAS is intended not to supplant any current logistics planning tools, but rather to fill a void in Class IX sustainability assessment. It offers capabilities that complement existing methods for measuring and reporting readiness, computing spares requirements, and the like.

Approach

The approach taken by VAS can be broken down into three steps. First, VAS projects weapon system availability rates across a specified scenario as a dual function of operationally generated demands and the capacity of the logistics system to meet those demands. A comparison of projected availability rates and specified availability goals yields an indication of the degree to which the combat force can be sustained. Next, VAS produces lists of the Class IX items that seem most likely to hinder achievement of the goals. Finally, after planners have had a chance to propose different strategies for improving performance, VAS can be used in a "what if" mode to compare and choose among them on the basis of their effect on sustainability.

The VAS concept is consistent with ongoing Army initiatives to modernize Standard Army Management Information Systems (STAMISes). VAS provides a means for effectively integrating data from a variety of old and new STAMISes and for exploiting the advantages of more accurate, timely reporting.

Potential Users and Uses

VAS is a broadly applicable tool aimed at sustainment planners throughout the Army. Its potential users reside at echelons ranging from divisions and corps to theaters, Major Commands (MACOMs), and contingency task forces to the national level. Among field users, VAS is likely to be of greatest interest to the G4 (a command's principal staff officer for logistics) and the Assistant Chief of Staff for Materiel (ACSMAT) and Materiel Management Center (MMC) of the attached support command. At the national level, primary users may include Weapon System Managers (WSMs), Program/Project Managers (PMs), the Materiel Management and Readiness Directorates of Army Materiel Command (AMC) and its Major Subordinate Commands (MSCs), and developers of logistics concepts and doctrine at the Combined Arms Support Command (CASCOM) and elsewhere.

The potential uses of VAS are as diverse as its community of users. Some important applications are:

- Assessing and improving the supportability of existing operation plans (OPLANS)
- Evaluating and choosing among alternative courses of action (COAs) during OPLAN development
- During peacetime, identifying effective strategies for overcoming potential wartime problems
- Examining new concepts and establishing new doctrine (e.g., regarding support structures and policies)
- Exploring cost reduction strategies and weighing tradeoffs among different resources (e.g., supply, maintenance, and transportation)
- Formal reporting of unit sustainability.

FUTURE STEPS

VAS addresses an important yet often overlooked aspect of logistics. If its promise can be fulfilled, it will improve the relevance and effectiveness of sustainment planning, and hence the warfighting capability of the combat force. However, in many respects, VAS is still in the conceptual stage of development. Several important issues remain to be resolved before full-scale implementation can be considered. These fall most often into the categories of:

x

- Feasibility
- Costs vs. benefits
- Usability.

We are confident that, over time, these issues can be settled to the Army's satisfaction. Nonetheless, efforts to identify and deal with pertinent questions should proceed apace.

Many key questions regarding VAS can best be answered by hands-on experience. We recommend that the Army construct and operate a series of incrementally expanding prototypes for this purpose. Prototypes offer several advantages over immediate implementation. They can be contained within a controlled environment, thereby avoiding widespread disruption of everyday business. They allow problems to be identified and corrected, and concepts and methodology to be refined and improved before becoming deeply committed to a particular course of action. Finally, they are less expensive and more easily managed. Experience acquired in prototyping may help the Army avoid costly pitfalls during full-scale implementation.

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The authors wish to express their appreciation to a number of RAND colleagues for helping to shape the ideas contained in this report. Irving Cohen offered valuable insights on the proper roles and functions of VAS and VISION as a whole. He, Thomas Lippiatt, and Raymond Pyles laid much of the groundwork for linking sustainability assessments to the dynamic needs of the combat force. Patricia Boren and William Stringer provided many useful suggestions as to how Army information systems can be used or adapted to supply the data requirements of VAS. Karen Isaacson clarified a number of technical questions regarding the Dyna-METRIC model and pointed out several areas that need enhancement. Craig Moore and Brian Leverich furnished thoughtful and substantive reviews that improved both content and organization. Regina Sandberg and Betsy Sullivan prepared several draft copies of the manuscript. Jeanne Heller provided expert editorial assistance.

Throughout the process of concept formulation, we enjoyed the active participation and counsel of several members of the Army logistics community. Cecilia Butler, Jeff Crisci, and COL Terry Chase of the Strategic Logistics Agency, and Larry Brown of the Combined Arms Support Command, were instrumental in providing support and access to various Army organizations and information sources. Our work also benefited from the comments and suggestions of the Readiness-Based Maintenance System Technical Working Group as well as other individuals too numerous to mention.

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ABBREVIATIONS

ACSMAT	Assistant Chief of Staff for Materiel
ADVANCE	Automated Data Validation and Netting Capability Establishment
ALB	AirLand Battle
ALB-F	AirLand Battle-Future
AMC	Army Materiel Command
AMSS	Army Materiel Status System
ASL	Authorized Stockage List
ATCCS	Army Tactical Command and Control System
BMS	Battlefield Maintenance System
C2	Command and Control
CAA	Concepts Analysis Agency
CASCOM	Combined Arms Support Command
CMMC	Corps Materiel Management Center
COA	Course of Action
COEA	Cost and Operational Effectiveness Analysis
CONUS	Continental United States
COSCOM	Corps Support Command
CSSCS	Combat Service Support Control System
DISCOM	Division Support Command
DMMC	Division Materiel Management Center
DOSup	Depth of Supply
DRIVE	Distribution and Repair in Variable Environments
DS	Direct Support
DSESTS	Direct Support Electrical Systems Test Set
Dyna-METRIC	Dynamic Multi-Echelon Technique for Recoverable Item Control
EAC	Echelons Above Corps
EHAT	Equipment Historical Availability Trend
EMC	Equipment Mission Capability
EOH	Equipment On Hand
FEDC	Field Exercise Data Collection
FMC	Fully Mission Capable

FSB	Forward Support Battalion
FVPDS	Fielded Vehicle Performance Data System
GS	General Support
IFTE	Integrated Family of Test Equipment (formerly Intermediate Forward Test Equipment)
JS	Joint Staff
LEA	Logistics Evaluation Agency
LOGNET	Logistics Data Network
LRU	Line Replaceable Unit
MACOM	Major Command
MMC	Materiel Management Center
MRSA	Materiel Readiness Support Activity
MSB	Main Support Battalion
MSC	Major Subordinate Command
MTD	Maintenance Task Distribution
NFMC	Non-Fully Mission Capable
NSN	National Stock Number
NSNMDR	National Stock Number Master Data Record
ODCSLOG	Office of the Deputy Chief of Staff for Logistics
OPLAN	Operation Plan
OPORDER	Operation Order
OSC	Objective Supply Capability (formerly Objective Supply System)
OSD	Office of the Secretary of Defense
PM	Program Manager or Project Manager
PMR	Provisioning Master Record
PROLOGUE	Planning Resources of Logistics Units Evaluator
RBMS	Readiness-Based Maintenance System
RIDB	Readiness Integrated Data Base
RO	Requisitioning Objective
ROSup	Range of Supply
SAM	Sustainability Assessment Module (Air Force—see WSMIS)
SAMS	Standard Army Maintenance System
SARSS	Standard Army Retail Supply System
SDC	Sample Data Collection

SESAME	Selected Essential-Item Stockage for Availability Method
SIMS-X	Selective Item Management System-Extended
SLA	Strategic Logistics Agency
SMI	Selectively Managed Item
SORTS	Status of Resources and Training System
SRA	Special Repair Activity
SRU	Shop Replaceable Unit
STAMIS	Standard Army Management Information System
TAACOM	Theater Area Army Support Command
TACOM	Tank-Automotive Command
TAMMC	Theater Area Materiel Management Center
TAV	Total Asset Visibility
TIS	Thermal Imaging System
TLRS	Total Logistics Readiness and Sustainability
TRADOC	Training and Doctrine Command
TRU	Thermal Receiver Unit
TSTS	Thermal Systems Test Set
ULLS	Unit Level Logistics System
VAS	VISION Assessment System
VISION	Visibility of Support Options
VTMR	Variance-to-Mean Ratio
WOLF	Work Order Logistics File
WRSK	War Readiness Spares Kit (Air Force)
WSM	Weapon System Manager
WSMIS	Weapon System Management Information System (Air Force)

1. INTRODUCTION

In today's complex geopolitical environment, the roles and missions of the U.S. Army are far less clearly defined than in the recent past. The Army's long-standing preoccupation with a high-intensity European war is being replaced by an orientation toward regional contingencies. This shift is accompanied by a great deal of uncertainty regarding such factors as the location of future conflicts, the nature of the U.S. role (e.g., whether combat or support), the capabilities of the threat, the duration and intensity of combat operations, and the environment in which they will be conducted.¹ These considerations weigh heavily in the Army's evolving view of both combat and logistics.

Despite the fundamental changes prompted by the emerging focus on contingencies, however, some tenets of Army doctrine remain constant. Among these is the premise that at any level of conflict, a necessary ingredient of success will be the ability of the logistics system to *sustain* the activities of the combat force.² The task of sustainment presents a dual challenge in planning and execution. No amount of planning can fully safeguard against all the uncertainties of war. Hence, in execution, the logistics system must be responsive and adaptive. On the other hand, there are practical limits to these qualities. Careful planning can mitigate the demand for *extreme* responsiveness and *constant* adaptation.³ Moreover, it can improve the ability of the system to adapt *effectively* when the need arises. In the longer term, it can lead to support structures and policies that are cost-effective and robust across a wide range of potential scenarios. These characteristics seem especially desirable as the Army enters a period that is at once more fiscally constrained and less certain than before.

¹Operation Just Cause (in Panama) and Operation Desert Storm (in Southwest Asia) represent but two points within a broad spectrum of possibilities.

²Sustainment is an important doctrinal element of both AirLand Battle (ALB) and AirLand Battle-Future (ALB-F). See FM 100-5, *Operations*, Headquarters, Department of the Army, Washington, D.C., May 1986, and GEN J. W. Foss, "Airland Battle-Future," *Army*, February 1991, pp. 20-37, respectively.

³Foss discusses the balance between "anticipation" (in some sense, synonymous with planning) and "improvisation" (adaptation).

REASONS FOR STUDYING CLASS IX

Obviously, sustainment involves many categories of resources (e.g., personnel, food, fuel, ammunition, and spare parts). In this report, we have chosen to concentrate on spare parts (i.e., Class IX items) for two principal reasons. First, Class IX is becoming increasingly critical to warfighting capability as the Army gravitates toward smaller numbers of expensive, high-technology weapon systems.⁴ The effectiveness of these weapon systems depends in large measure on the continuing availability of Class IX assets. The importance attached to Class IX sustainment by the Army can be seen in such costly initiatives as the Special Repair Activity (SRA) for the AH-64 Apache helicopter and the widespread use of contractor maintenance during Operation Desert Storm. Historically, Class IX has not received a great deal of attention from planners, perhaps because it constitutes a relatively light transportation burden; however, as the high-tech trend continues, we expect this viewpoint to change.

The second reason for studying Class IX is that it brings together several key aspects of logistics, including supply, maintenance, transportation, and procurement. Also, many of the difficulties and uncertainties that afflict the logistics system in general are represented here (some of these complicating factors are described below). Although these may have different manifestations in other resource categories, we believe that an examination of Class IX sustainment planning can provide useful insights into those areas.

SUSTAINMENT PLANNING AND THE ROLE OF ASSESSMENT

The scope and content of sustainment planning vary according to the level at which the planning is conducted, the time period to which it applies, and the degree of urgency that attends it. Responsibility for planning is spread throughout the logistics community; it begins at division and corps level and extends to such national-level entities as Army Materiel Command (AMC), the Combined Arms Support Command (CASCOM), and the Office of the Deputy Chief of Staff for Logistics (ODCSLOG).

Issues and assumptions are often a function of whether planning applies to the long term or the short term. When planners take a long-term view (say, a year or more into the future), they typically deal only with notional forces and scenarios. The questions they address

⁴This tendency is an underlying theme of ALB-F.

are more likely to be abstract and oriented toward doctrine, requirements determination, and cost control. In contrast, short-term planning is usually driven by a specific set of circumstances and may reflect actual force postures, asset balances, and logistic capabilities; operational needs and objectives are also apt to be more clear-cut. Examples include preparation for a large-scale training exercise and development of a warfighting operation plan (OPLAN) to meet an existing or emerging situation.

A third dimension of planning is its underlying sense of urgency. *Deliberate* planning is a meticulous, unhurried process that goes on continuously in peacetime. It addresses in detail all aspects of logistic support associated with both full-fledged and conceptual OPLANS. In the Class IX arena, some relevant topics are allocation of spare parts, sizing and location of maintenance facilities, and utilization of transportation resources. Long-term planning is usually deliberate in nature; however, deliberate planning need not always focus on long-term concerns.

One of the goals of deliberate planning is to anticipate the ways in which a scenario might eventually deviate from its envisioned course. Inevitably, though, as conflict becomes imminent, new information and unfolding circumstances will tend to invalidate portions of even the most thoroughly prepared plans; in the worst case, a situation might arise so suddenly and unexpectedly that no applicable deliberate plan can be found. This is the province of *crisis-action* or *time-sensitive* planning. As suggested by its name, time-sensitive planning generally takes place in an atmosphere of considerable urgency, with no room for the sort of exhaustive analysis that characterizes deliberate planning.⁵ Whether it entails modifications to an existing OPLAN or construction of an entirely new one, a key aspect of time-sensitive planning is the assessment of alternative courses of action (COAs) open to the combat commander. A series of Army field manuals outlines the critical role of such assessments in the development of OPLANS at all echelons.⁶ These manuals emphasize the importance of logistic constraints in combat planning; they identify supportability

⁵For a broader discussion of deliberate and time-sensitive planning, see AFSC Pub 1, *The Joint Staff Officer's Guide 1991*, National Defense University, Norfolk, Virginia, 1991.

⁶See, for example, FM 63-2, *Combat Service Support Operations—Division*, Headquarters, Department of the Army, Washington, D.C., November 1983; FM 63-3J, *Combat Service Support Operations—Corps*, Headquarters, Department of the Army, Washington, D.C., August 1985, and FM 63-5, *Combat Service Support Operations—Theater Army*, Headquarters, Department of the Army, Washington, D.C., February 1985.

as an essential characteristic, and often, a deciding factor in choosing among several options.

Clearly, the nature of sustainment planning is determined in large part by the setting in which it occurs. In all cases, however, planners are called upon to compare and choose among different strategies on the basis of their relative strengths and limitations. Therefore, planners need decision support tools that allow them to assess the likely effects of those strategies on logistics performance. Some of the questions that must be addressed by these assessment tools are discussed below.

THREE FUNDAMENTAL PLANNING QUESTIONS

Whether sustainment planning takes place at the field user or national level, whether it is long-term or short-term, deliberate or time-sensitive, three fundamental questions should remain uppermost in the minds of planners:

- Can the logistics system support operational needs and objectives throughout the course of a planned conflict?
- If not, where and when are problems most likely to emerge, and how serious are they likely to be?
- What can be done *beforehand* to avoid or mitigate those potential problems?

Can Operational Needs Be Supported?

To answer the first question, planners must begin by estimating the time-varying demand for logistic resources that will be generated by the total force.⁷ Then, they must assess whether existing resources are adequate to meet that demand. Beyond simple counting of on-hand assets, planners need to acknowledge the capabilities of the support structure to repair and return broken items and to procure and deliver replacements. In addition, they should account for the

⁷Actually, any such estimation depends upon an even more fundamental step. Operations planners and logistics planners must work together to translate operational objectives (e.g., "use this force to seize that position") into terms that are logically meaningful (e.g., "provide resources sufficient to sustain this number of fully mission capable (FMC) weapon systems in these combat postures over this interval of time"). This crucial link between operations and logistics—which presently is not well developed—is the subject of a forthcoming concept paper about VISION's implications for logistics command and control.

ways in which policies and procedures either exploit or constrain the potential of the entire system. In conducting their assessments, planners should not limit their view to the resources of their own organizations, but should seek a multi-echelon perspective. For instance, corps-level planners ought to be aware of theater resources upon which they can draw; at the same time, they must recognize the individual needs of their subordinate units and attempt to coordinate them in such a way as to maximize overall combat capability. Finally, in light of the uncertain nature of all military operations, planners must make allowances for unanticipated events. Whenever time permits, they should assess the consequences of scenario variations, combat damage, loss of assets, and the like. In this fashion, they will develop a better understanding of—and perhaps be able to improve—the robustness of the logistics system.

If Not, Why Not?

Identifying and quantifying potential problems is an essential part of sustainability assessment. When assessments indicate that acceptable levels of support cannot always be expected throughout a conflict, it is not enough merely to know that the logistics system is somehow deficient. The source, timing, and magnitude of potential problems must all be estimated. Problems may take many forms, including inadequate supplies of spare parts, shortfalls in maintenance or transportation capacity, and temporary bottlenecks in key logistics functions. A good assessment tool must help planners to detect those areas that seem likely to present the greatest obstacles. Otherwise, logisticians might channel valuable time, energy, and resources into solving secondary problems while overlooking those that will eventually grow to be the true limiters of combat sustainment.

What Can Be Done About It?

Planners must develop timely strategies for overcoming potential problems (or at least reducing them to manageable proportions). To help address this third question, an assessment tool should provide planners with a convenient framework for proposing and evaluating a broad range of approaches and adaptations to existing plans. Because there are often multiple solutions to a single problem (e.g., accelerating procurement, increasing maintenance throughput, or reallocating assets to meet a supply shortfall), this tool must be able to recognize a wide array of decision parameters and accurately represent their interactions and effects on the performance of the logistics system. It is here that the planning and execution functions come

together; assessment outcomes can furnish motivation and direction for those who execute the plan.

COMPLICATING FACTORS IN PLANNING

Even in a relatively stable environment, the three questions presented above are difficult to answer simply because of the enormous scope of operations to which they apply. And unfortunately, the future does not promise to be stable. Planners will no doubt encounter numerous complications, many having to do with inherent systemic uncertainty and the growing complexity of the logistics support structure.

Systemic Uncertainty

Uncertainty in many forms pervades the logistics system. Even during peacetime, when operational activity is fairly steady and predictable, logisticians find it hard to accurately forecast Class IX demand. This is largely due to the high variability that characterizes many component failure processes.⁸ As troublesome as this variability may be, however, it pales in comparison to the uncertainty of wartime.

Accounting for wartime uncertainty poses problems in all phases of planning. Today, for instance, as the relative likelihood of a general European war recedes, deliberate planners face growing doubt as to the location of future conflicts. As the number and diversity of potential contingency sites increase, so too does uncertainty regarding the capacity of the local infrastructure to sustain a deployed force; this burdens planners with the need to consider a broader array of support concepts. Even more problematical than location are the scenario characteristics that drive demand for logistic resources; these include the scale, intensity, and duration of conflict.

In combat, uncertainty takes shape in such factors as surprise enemy actions, the need for U.S. forces to respond to those actions and to exploit chance opportunities, battle damage, and deviation from expected personnel and equipment performance standards. In a dy-

⁸To get a better sense of this variability, see M. B. Berman, D. W. Melver, M. L. Robbins, and J. Schank, *Evaluating the Combat Payoff of Alternative Logistics Structures for High-Technology Subsystems*, RAND, R-3673-A, October 1988. The other military services suffer from the same problem. See, for example, G. B. Crawford, *Variability in the Demands for Aircraft Spare Parts: Its Magnitude and Implications*, RAND, R-3318-AF, January 1988.

namic environment, rapidly changing operational objectives, force postures, and support priorities can place rigorous demands on time-sensitive planning. Under such conditions, planners will be obliged to continually revise their estimates of logistic needs, conduct hasty assessments of COA supportability, and identify and coordinate appropriate responses by the execution system.

Structural Complexity

Over the years, the Army has demonstrated its preference for high-tech hardware designs. The M1 tank, the M2 infantry fighting vehicle, and the AH-64 helicopter, for example, derive much of their capability and lethality from advanced electronic and electro-optical devices. However, the rising cost of spare parts for such weapon systems makes it increasingly unaffordable to "buy out" uncertainty in Class IX demand merely by procuring additional safety stocks. Instead, the Army looks to an extended, multi-echelon maintenance and distribution structure to provide timely repair and return of unserviceable assets.⁹ The resulting interaction of different organizations, functions, and management systems presents a serious problem in integration. Whether during peacetime or wartime, planning is hampered by the lack of a single objective—for instance, maximizing weapon system availability—to harness the separate decisionmaking processes and provide a unifying measure against which to assess alternative strategies.¹⁰

The complications arising from structural complexity are magnified by the expanding range of potential scenarios. The standard, doctrinal logistics structure intended to sustain a general European war may not be sensible or even feasible in the case of a short, low-intensity, or geographically remote contingency operation. Instead, each new conflict might best be supported by an ad hoc structure to be selected only when its dimensions become apparent: the preliminary design and final tailoring of such structures constitute a difficult challenge in both deliberate and time-sensitive planning.

⁹Typically, high-tech component repair involves the participation of direct support (DS) and general support (GS) units in the field as well as more specialized facilities in theater or in the continental United States (CONUS) depot system.

¹⁰Currently, each organization operates largely on the basis of internal performance measures that are not necessarily related to those of other organizations or to the ultimate needs of the combat force. Efficient use of resources is often viewed as an end, without sufficient consideration of whether "inefficient" methods can sometimes spell more effective support (e.g., routinely moving partial loads of expensive spare parts in order to shorten the delivery pipeline and reduce the likelihood of critical supply outages).

LIMITATIONS OF CURRENT METHODS

At present, Army logisticians have few direct, quantitative methods for addressing the three fundamental questions of Class IX sustainment planning. Several established planning tools are somewhat related to this topic, but most were designed to serve other purposes. Although they provide valuable assistance to logisticians in their respective areas, they usually exhibit at least one or two of the following key shortcomings with regard to sustainment planning and assessment:

- Emphasis on readiness at the expense of sustainability
- Limited wartime and weapon system orientation
- Emphasis on supply problems and solutions at the expense of other functions (e.g., maintenance and transportation)
- Emphasis on requirements at the expense of assessment
- Limited attention to uncertainty and the potential role of management adaptation.

Before elaborating on each of these, we should note that not all are shortcomings in an absolute sense. For instance, both readiness and requirements are issues of great concern to planners, and rightly so. What is troublesome is the absence of corresponding methods that focus on sustainability and assessment.

Readiness vs. Sustainability

The twin subjects of readiness and sustainability are extremely important to logisticians.¹¹ A unit's readiness reflects its preparedness for embarking on an assigned mission. Formal measures of readiness are defined for four aspects of a unit's condition.¹² In the category of

¹¹Here, as throughout this report, it is understood that when we speak of readiness and sustainability, we do so purely from the standpoint of *equipment* or *materiel*. Also, we adhere to the terms "readiness" and "sustainability" primarily to emphasize the distinction between the two and to reinforce the idea that more attention needs to be given to sustainability. The Status of Resources and Training System (SORTS), which applies to all the armed services, concentrates upon unit "status," which purports to be neither readiness nor sustainability. Thus, in connection with SORTS, proper usage—as set forth by the Joint Staff (JS)—substitutes the word "status" for "readiness." See *Status of Resources and Training System*, Joint Staff, Memorandum of Policy 11, March 1990.

¹²These cover personnel strength, training, and materiel posture. See AR 220-1, *Unit Status Reporting*, Headquarters, Department of the Army, Washington, D.C., August 1988.

materiel supported by Class IX, a dual measure is used; it consists of equipment on hand (EOH, essentially a fill rate against an authorized level of reportable items such as tanks, trucks, and radios) and equipment mission capability (EMC, the percentage of time that equipment was fully mission capable during the past month).¹³ Periodic reporting enables Army leaders, the Joint Staff, and the logistics community to monitor readiness across the Army. Recent advances in logistics data automation are leading to improvements in the timeliness and accuracy of the reporting process.¹⁴

In contrast, a unit's sustainability describes not its starting potential, but its staying power—its capacity to endure through conflict to the conclusion of its mission. In many ways, sustainability is much more difficult to quantify than is readiness. Readiness is directly observable; it can be calculated explicitly on the basis of “snapshots” of past and present status. Sustainability, on the other hand, involves future performance and cannot be known precisely; it can only be estimated and projected. Unsurprisingly, current measures of sustainability are also vaguer and less satisfactory than those of readiness. For example, readiness is reported for specific weapon systems and end items (e.g., the M1 tank or AH-64 helicopter); sustainability has no such high-level focus. Class IX sustainability is typically gauged in terms of range of supply (ROSup, the number of Class IX items that are fully stocked relative to the total number that have a stockage requirement—somewhat akin to a fill rate) and depth of supply (DOSup, an aggregate indicator of the relative richness of stockage).

Although both readiness and sustainability are essential elements of combat power, logisticians seem unduly preoccupied with the former. Even in AR 700-138, *Army Readiness and Sustainability*, only limited attention is given to sustainability. Whereas an elaborate system has evolved to track readiness, there are no comparable mechanisms for routinely determining how well units can sustain a fight once they have begun it. Perhaps this situation exists because sustainability is

¹³See AR 700-138, *Army Logistics Readiness and Sustainability*, Headquarters, Department of the Army, Washington, D.C., March 1990.

¹⁴Currently, units submit readiness reports to the Readiness Integrated Data Base (RIDB) at the Materiel Readiness Support Activity (MRSA). MRSAs subsequently generates a variety of RIDB outputs for dissemination throughout the Army. RIDB is described in *Readiness Integrated Data Base (RIDB) User's Manual*, USAMC Materiel Readiness Support Activity, Lexington, Kentucky, June 1988. By tapping directly into unit-level data systems, the Army Materiel Status System (AMSS) promises to eliminate manual reporting and provide all parties with continuous, near real-time access to readiness information. See L. Kirkham, *Functional Requirements for Automating Materiel Readiness Reporting in the United States Army*, Headquarters, U.S. Army Materiel Command, Alexandria, Virginia, September 1989.

a more tenuous concept that is correspondingly harder to quantify and report in meaningful terms. However, given the importance of sustainment to wartime success, it seems worthwhile to pursue a more advanced capability in this area.

Lack of a Wartime and Weapon System Perspective

Although the readiness reporting system can function during wartime, there is no convenient, systematic way for planners in peacetime to project wartime readiness rates and thereby obtain an estimate of sustainability.¹⁵ Clearly, extrapolated peacetime readiness trends have no special relevance in the context of an intense and demanding wartime environment. Measures of supply condition such as ROSup and DOSup are more useful, but they too suffer from significant flaws. Although they tend to be correlated to sustainability, the connection is not always reliable. High values of ROSup and DOSup can mask shortfalls of a few key items which by themselves might be enough to seriously constrain overall EMC. Moreover, as Class IX item-oriented measures, they cannot be tied to individual weapon systems; this may limit their appeal and usefulness to combat commanders.

Supply vs. Other Functional Areas

Many current planning tools are based on mathematical inventory models of Class IX supply. Although supply is central to sustainment, it is overly simplistic to view all problems and potential solutions purely in those terms. Many apparent supply problems can be blamed equally on a lack of capacity or responsiveness in other areas such as maintenance and transportation. Similarly, many worthwhile solutions can involve improvements in nonsupply functions. To the extent that models fail to recognize or accommodate such trade-offs, they restrict the ability (and perhaps the inclination) of planners to fully consider them.

This is not to say that nonsupply functions are entirely ignored. A variety of planning tools and performance measures exist in these areas as well.¹⁶ However, it is not enough to consider supply, mainte-

¹⁵We can think of a sequence of readiness projections over the course of a wartime scenario as constituting such an estimate.

¹⁶The PROLOGUE (Planning Resources of Logistics Units Evaluator) model, for instance, evaluates actual logistics manpower levels, materiel handling capability, and transportation capacity against requirements for different wartime scenarios. There are several PROLOGUE documents, including, *PROLOGUE Maintenance Module*

nance, transportation, and other functions in a piecemeal fashion. It is their interaction and integration that are important to achieving sustainment goals. A unifying tool is needed.

Requirements vs. Assessment

The question of logistic requirements is a fundamental one: What resources are needed to sustain the combat force for the duration of its mission? A number of useful tools have been developed to help planners examine this subject.¹⁷ However, none is well adapted for assessment purposes. Specifically, the tools do not directly address the question of how well a combat force can be sustained *with the resources at hand*. Moreover, because of the general lack of an appropriate theoretical foundation, these tools tend to be supply-oriented. That is, they compute supply requirements based on fixed estimates of capacity and performance in nonsupply functions. As we have argued, however, planning solutions need not be confined to changes in asset levels. They can involve a mix of assets, structures, and policies. Tools that can assess a variety of mixes would be helpful because planners are often confronted by a limited array of options, and pure supply solutions are not always feasible, timely, or affordable.¹⁸

Uncertainty and Adaptation

A recognition of the inevitability of unforeseen events is essential in sustainment planning. So too is an appreciation for the potential

User's Manual, U.S. Army Logistics Evaluation Agency, New Cumberland, Pennsylvania, November 1987; *PROLOGUE Unit Resources Evaluation System User's Manual*, U.S. Army Logistics Evaluation Agency, New Cumberland, Pennsylvania, January 1988; and *PROLOGUE Supply Module User's Manual*, U.S. Army Logistics Evaluation Agency, New Cumberland, Pennsylvania, February 1989.

¹⁷SESAME (Selected Essential-Item Stockage for Availability Method), for example, focuses upon the provisioning process. It (or its derivatives) is used in budget forecasting and to compute Class IX stockage level objectives for both field users and national-level organizations. LOGNET (Logistics Data Network) deals with a range of resource categories, including Class IX, fuel, ammunition, and the end items themselves. It considers how to balance assets across units prior to deployment and compares expected consumption of resources to available quantities. See, respectively, AMC Pamphlet 700-18, *User's Guide for the Selected Essential-Item Stockage for Availability Method (SESAME) Model*, Headquarters, U.S. Army Materiel Command, Alexandria, Virginia, July 1983; and *The Logistics Data Network (LOGNET) System Concept Paper: Functional Requirements Document, Milestone One*, U.S. Army Logistics Evaluation Agency, New Cumberland, Pennsylvania, April 1987.

¹⁸If and when it can be developed, a multi-dimensional requirements model would be a powerful instrument. Until then, there is a role for both single-dimensional requirements models and assessment models that allow planners to investigate promising alternatives in a multi-dimensional space.

benefits of various adaptive strategies when such events occur. No planning tool can account for every source of uncertainty; indeed, by their very nature, many of these sources are unknowable in advance. Planners must cope by extending their assessments to include as many contingencies as time will allow. In doing so, they might at least establish reasonable bounds on expected future performance. Also, they might be able to devise support structures, policies, and asset allocation rules that are robust in the face of uncertainty (i.e., that seem to offer consistently satisfactory performance across a broad spectrum of possible scenarios).

The scope of adaptation is scarcely smaller than that of uncertainty. Although planners cannot be expected to anticipate every form of improvisation that will occur, they must at least be aware of a number of commonly practiced measures.¹⁹ A thorough assessment of such adaptations under a variety of conditions can reveal their respective advantages and limitations and provide a good sense of where and when they are most likely to offer a high payoff. Even if used infrequently, an established "menu" of adaptations can improve the effectiveness and timeliness of wartime logistics execution.

The need for an exploratory approach to account for uncertainty and adaptation means that planning tools must be flexible, easy to use, and fairly fast. If planners at all echelons of the logistics system had access to such tools, they would be able to conduct relevant exercises in a routine, everyday fashion. Models that are rigidly structured, extremely detailed, and slow to run have limited value in such a context. Despite their strengths in representing many different facets of the logistics system, they are better suited for other purposes.²⁰

¹⁹ Examples include cross-leveling, or the redistribution of assets among units; controlled exchange, or the removal of serviceable components from an already unserviceable end item to facilitate the repair of another end item; and sharing of maintenance capability when one unit is overburdened and another is not.

²⁰ The Total Logistics Readiness and Sustainability (TLRS) model is a case in point. It is unparalleled in its depiction of logistic resources and processes. However, TLRS is also very complex, data-intensive, and slow; it operates on a two-year cycle in conjunction with the OMNIBUS exercise, which evaluates the Army's ability to prosecute a war in accordance with the scenarios specified in the Defense Planning Guidance. See *Total Logistics Readiness and Sustainability 1991 (TLRS 91): Vol. 1—Methodology*, U.S. Army Logistics Evaluation Agency, New Cumberland, Pennsylvania, January 1990.

THE NEED FOR ENHANCED SUSTAINABILITY ASSESSMENT

Assessment is an important part of sustainment planning, which in turn is an important contributor to combat capability. Although the Army has developed useful planning tools in a number of related areas, all of them have significant shortcomings when applied to sustainability assessment. The Army needs a tool specifically designed for sustainability assessment that brings with it an orientation toward wartime support and weapon system management, an integrated view of logistics echelons and functions, and the flexibility to consider different forms of uncertainty and adaptation. The remainder of this report describes the VISION (Visibility of Support Options) Assessment System and its suitability for Army needs.

Organization of This Report

Section 2 presents the objectives and characteristics of the VISION Assessment System (VAS) and identifies the types of planning for which it would seem to be appropriate. Section 3 describes its proposed mode of operation and summarizes its data requirements and primary output products. Section 4 lists several research issues which must be resolved before full system implementation can be undertaken. Section 5 recommends the development of prototypes to test the principles of VAS and to explore the feasibility of implementation by the Army. Appendix A provides a brief overview of the VISION project (of which VAS is but a part). Appendix B outlines the principal characteristics of the Dyna-METRIC model, which is the chief methodological component of VAS.

2. THE VISION ASSESSMENT SYSTEM CONCEPT

Readiness is a major factor in all phases of logistics planning and execution. Its influence is due primarily to its fundamental connection to military capability, but is further reinforced by its high degree of visibility. The Army has well-established procedures for measuring, reporting, and monitoring equipment readiness at all echelons; with the advent of AMSS, these will become even more effective.

Sustainability is no less important than readiness. Unfortunately, however, it receives considerably less attention, certainly in the Class IX arena, and perhaps elsewhere as well. This is not so much a deliberate oversight as an indication that sustainability is much harder to quantify and report—and hence, to manage.

The purpose of the VISION Assessment System (VAS) is not to overhaul or replace current systems for managing equipment readiness. Rather, it is to provide an extended view that encompasses sustainability and so enables logisticians to regard the two issues on a more equal footing. VAS offers an opportunity to improve the effectiveness and relevance of sustainment planning by focusing on the three fundamental planning questions identified in the previous section: *Can operational needs be supported? If not, why not? And what can be done about it?*

Although the Army employs a variety of logistics planning tools, VAS often differs from them in orientation and intended applications. In the remainder of this section, we outline its approach and describe the characteristics that most distinguish it from existing systems. Subsequently, we review some of the potential users and uses of VAS.

GENERAL APPROACH

VAS is a decision support system for sustainment planners throughout the Army. It facilitates the planning process by providing a means to assess the supportability of operational plans and objectives in light of logistic resources and capabilities. VAS measures performance in terms of the levels of *weapon system availability* that the logistics system is projected to yield.¹ A sequence of such projections over the course of a planned scenario can be compared to availability

¹Weapon system availability is defined here as the proportion of all weapon systems that are fully mission capable (FMC) at a point in time.

goals specified by the combat commander; the result can be construed as the sustainability of the combat force.

In conjunction with its availability projections, VAS generates lists of those Class IX items deemed most likely to obstruct the attainment of availability goals. These lists, together with more detailed reports of flows and bottlenecks throughout the system, can serve as the basis for proposing and selecting strategies to improve performance.

CHIEF CHARACTERISTICS

In Sec. 1, we discussed several key limitations that hamper the effective use of existing tools for sustainment planning purposes. These include a tendency to focus on current and historical readiness rather than future sustainability, a lack of attention to wartime and weapon system-oriented measures, and little scope for addressing many of the complicating factors in planning (e.g., the complex interaction of supply and nonsupply functions, uncertainty, and adaptation). VAS is designed to overcome these limitations; some of its more relevant characteristics are described below.

Forward-Looking Methodology

Trend analysis is one of today's most commonly used methods for predicting whether readiness can be sustained at acceptable levels in the future. The Equipment Historical Availability Trend (EHAT) report—an extract from RIDB—allows senior Army leaders to review readiness data for the past eight quarters and to gauge the size and direction of any notable statistical trends.² EHAT provides a good sense of where readiness has been but not necessarily of where it is going. Its value as a forecasting tool drops sharply whenever future circumstances are not expected to mirror those of the past—a condition that prevails often during peacetime and always when considering the transition from peace to war.

VAS offers an alternative to extrapolations based on past performance. It employs a direct, forward-looking approach to project future weapon system availability. VAS uses a mathematical model—Dyna-METRIC³ to represent the interaction between operational activity (which generates demand for logistic support) and the logistic resources and capabilities (e.g., spares, maintenance, and transporta-

²AR 700-138.

tion) that sustain such activity.³ Weapon system availability rates are projected over time as a function of the level of demand and the potential (or lack thereof) of the logistics system to deliver needed support. The VAS approach can be applied to any type of operational scenario. Its flexibility allows planners to explore a wide variety of cases, including those dynamic situations that clearly lie beyond the scope of trend analysis.

Wartime and Weapon System Orientation

Although planning is largely a peacetime activity, the primary focus of VAS remains on wartime issues and performance. This perspective accounts for its emphasis on sustainability rather than readiness alone. In addition, the Dyna-METRIC model has been designed to deal with several important aspects of combat operations, including:

- Dynamic operating tempos (optempos) to represent the uneven pace of battle
- Time-varying, force-specific weapon system availability goals to represent differential support objectives
- Attrition of end items
- Battle damage and repair of Class IX items.

Beyond having a wartime orientation, VAS is intended to improve the operational relevance of the measures used in sustainment planning—hence, its attention to weapon system availability.⁴ From the standpoint of combat capability, planning projections expressed in terms of weapon system availability are more meaningful than such intermediate, item-related measures as ROSup and DOSup. Because they are more likely to be understandable and useful to combat commanders, they may increase the visibility of logistics considerations during operations planning.

³See App. B for a description of the Dyna-METRIC model.

⁴Improving operational relevance in this regard is a long-standing goal of the Department of Defense and the Army. See, for example, *Secondary Item Weapon System Management: Concept and Implementation Plans*, Department of Defense, April 1986; *Army Implementation of the DoD Weapon System Management Action Plan*, Department of the Army, Assistant Secretary for Installations and Logistics, March 1986; and *Assessing Sustainability: The Report of the Sustainability Assessment Task Force*, Department of Defense, Office of the Assistant Secretary of Defense (Production and Logistics), December 1988.

Multi-Echelon, Multi-Functional Structure

The size and complexity of the Army's logistics system and the potential diversity of ad hoc contingency support concepts require that assessment tools be able to represent a wide variety of structures. VAS provides such flexibility. It allows planners to tailor their analyses with respect to the number of echelons of logistic activity, the degree of connectivity among echelons and units, and the functional capabilities (e.g., supply, maintenance, transportation) of each unit.⁵

This integrated view of echelons and functions is an important element of sustainment planning. An examination of a single unit or echelon may overlook such significant conditions as unexpected resource shortfalls at lower echelons or the availability of extra backup capacity at higher echelons. Similarly, a piecemeal evaluation of functions may fail to capture the crucial interactions that determine the overall level of support that can be provided to the combat force. With VAS, planners will not only be able to detect weaknesses in specific areas—they will also be able to assess the effects of improvements in those areas on total system performance. Furthermore, VAS can help planners to identify worthwhile tradeoffs across echelons and functions and to realign capabilities accordingly.

Recognition of Uncertainty and Adaptation

VAS addresses the problem of planning under uncertainty in two ways. First, it is designed to be faster, more flexible, and easier to use than large and complex tools like TLRS. Although these attributes may spell some compromise in terms of model detail, they improve the ability of VAS to serve as a regular adjunct to sustainment planning at all echelons. If planners were to use VAS routinely to examine the implications of scenario variations and alternative support concepts, they would naturally be accounting for uncertainty in those areas. The greater the breadth of their exploration (even if conducted informally), the better their sense of how the logistics system might perform in an uncertain future. Finally, in consequence of this style of planning and assessment, planners may be more likely to find—and appreciate—robust solutions.

⁵Despite its relatively rich perspective, it is still possible to envision support structures that exceed the representational powers of Dyna-METRIC (see App. B for a description of model limitations). Moreover, in some instances, users are required to exercise special ingenuity in order to depict complex structures. There is certainly room for improvement and further generalization of the model in this regard.

Second, VAS deals with uncertainty from the standpoint of modeling methodology. Dyna-METRIC is a stochastic (rather than deterministic) model. That is, it incorporates elements of randomness into all major processes; for instance, it allows the use of highly variable demand patterns, random repair and transportation times, and repair cycle times that are affected by workload congestion and queueing. In practical terms, this approach means that model outputs are not simply point estimates; they also include confidence bounds that give an idea of the variability of projected performance. Such measures can be important when evaluating risk and comparing the robustness of different strategies.

No treatment of uncertainty is complete without due consideration of the adaptations that are (or can be) employed in response to unforeseen circumstances. Recognizing the role of adaptation is important in two respects. First, if some measures (e.g., controlled exchange) are commonly taken whenever difficulties arise, then planners must acknowledge that fact and account for the mitigating effect of such measures on otherwise poor projected performance. If a potential problem appears to be readily surmountable by means of adaptation, there is less reason to worry about it from a planning perspective—particularly if other problems seem to be more difficult to resolve. Second, by identifying a number of adaptations and assessing their effects under various hypothetical conditions, planners can prepare for situations in which they might be used to advantage. When the "right" sort of problem actually emerges, logisticians will have a better notion of what steps to pursue.

With VAS, planners are able to examine a range of adaptations, including controlled exchange, cross-leveling, lateral maintenance support between units at the same echelon, and prioritized maintenance and distribution. However, it must be noted that here, as in the area of uncertainty, the capabilities of VAS represent only a beginning. VAS can be a unique and valuable tool, but it by no means an ultimate one. Even if it is implemented in the near future, its development and refinement must continue as new ideas are brought forward.

EXPLOITATION OF ENHANCED INFORMATION SYSTEMS

One of the principal goals of the overall VISION project is to make better use of information to guide logistics planning and execution. VISION (and hence VAS) therefore goes hand in hand with the Army's ongoing enhancement of Standard Army Management Information Systems (STAMISes). Among other improvements, these

systems will provide more timely updating and wider accessibility of basic catalogue data and greater visibility of the current status of logistic resources. Progress to date is reflected in such initiatives as the Objective Supply Capability (OSC, formerly the Objective Supply System), Total Asset Visibility (TAV), the Standard Army Maintenance System (SAMS), and the Standard Army Retail Supply System (SARSS).⁶

Of course, the availability of accurate, up-to-date information is valuable only to the extent that it is properly exploited. If it is to have a significant, positive effect on decisionmaking, it must be complemented by the use of suitable decision support tools. VAS would be such a tool. By integrating data from different STAMISes within a unified representation of the support process, VAS offers planners new capabilities for projecting logistics performance, identifying problems, and developing timely solutions.

POTENTIAL USERS AND USES

VAS is a broadly applicable tool aimed at sustainment planners throughout the Army. Sustainment planning occurs at many echelons; it is practiced by divisions and corps as well as by such national-level organizations as AMC, CASCOM, and ODCSLOG (and, in the joint defense community but still of interest to the Army, by the Defense Logistics Agency and the U.S. Transportation Command, among others). At the field user level, primary users of VAS may include the G4 (a command's principal staff officer for logistics) and the Assistant Chief of Staff for Materiel (ACSMAT) and Materiel Management Center (MMC) of the attached support command.⁷ At the national level, primary users may include Weapon System Managers (WSMs), Program Project Managers (PMs), the Materiel Management and Readiness Directorates of AMC and its Major Subordinate commands (MSCs), and developers of logistics concepts and doctrine. Some potential uses of VAS at different echelons are suggested below.

⁶See *Objective Supply System Proof of Principle Demonstration: Evaluation Report*, Vol. I, Innovative Technology, Inc., McLean, Virginia, December 1988; *The Strategic Logistics Agency (SLA) Total Asset Visibility (TAV) Management Plan for Concept and Proof of Principle*, U.S. Army Strategic Logistics Agency, Ft. Belvoir, Virginia, March 1990; and *Combat Service Support Automation Architecture*, U.S. Army Combined Arms Support Command, Ft. Lee, Virginia, January 1989.

⁷Support commands are commonly designated according to the level at which they operate. Thus, we have Division Support Command (DISCOM), Corps Support Command (COSCOM), and Theater Area Army Support Command (TAACOM). An MMC may similarly be designated as a DMMC, CMMC, or TMMC.

Division and Corps Level Applications

At corps level and below, planners generally focus on short scenarios. In time-sensitive planning situations, the period of interest is likely to be only a few days at most. Here, the relevant questions concern the ability of logistics units to sustain weapon system availability in accordance with the combat commander's objectives, the proper disposition of scarce assets, the identification of potential problems, and the types and quantity of support to request from higher levels.⁸

During deliberate planning, planners may wish to explore a broader range of scenarios. These could include an assortment of brief (a few days long) vignettes intended to lay the groundwork for time-sensitive planning in the future. The objectives of such an exercise might be to assess sustainability, devise contingency asset allocation strategies, and identify likely areas of shortfall in a variety of different combat and support environments (e.g., highly mobile vs. static, armor-intensive vs. aviation-intensive, or mature theater vs. austere theater). Longer scenarios (perhaps ranging in duration from 15 to 30 days) could be used to address the same issues from the standpoint of a more protracted conflict. In addition, these might provide a context for evaluating the viability of new support concepts (e.g., the Battlefield Maintenance System (BMS) alternative to the traditional organizational/DS/GS structure), the robustness of different resource mixes (e.g., spares in a divisional Authorized Stockage List (ASL)), and related topics.⁹

⁸These topics are among the critical information needs of the corps G4, the CMMC commander, and the COSCOM ACSMAT, as reported in a study by the U.S. Army Logistics Evaluation Agency (LEA). This study also encompasses areas that lie somewhat beyond the scope of VAS, including unit recovery and reconstitution. See *Requirements Determination for SAMS-2 and SAMS-3 at the Corps and Theater Levels*, U.S. Army Logistics Evaluation Agency, New Cumberland, Pennsylvania, October 1989.

⁹Both BMS and ASL stockage policy are important issues of the day. BMS is an outgrowth of the Army's new ALB-F warfighting doctrine. It is described in *Operational Concept for the Battlefield Maintenance System (BMS)*, U.S. Army Ordnance Center and School, Draft TRADOC PAM 525-XX, Aberdeen Proving Ground, Maryland, August 1990. ASLs are receiving greater attention because of the move toward stock funding of previously "free issue" Class IX assets; this initiative will oblige units to operate within a spare parts budget and may lead them to be more conservative in their approach to provisioning and other aspects of materiel management. For a discussion of stock funding, see K. L. Moore, "Stock Funding of Depot-Level Reparables," *Army Logistian*, July-August 1991, pp. 2-6.

Theater, MACOM, and Task Force Level Applications

Between divisions corps and the national level are theaters, Major Commands (MACOMs), and—in consequence of the current orientation toward regional contingencies—task forces. Planners at this echelon have many interests in common with their lower-level counterparts, but their planning horizons tend to be significantly longer and they face a greater variety of issues. Scenario durations are apt to be measured in weeks rather than days and to cover entire operations and campaigns rather than single engagements. The expanded scope of theater-level planning introduces such variables as the need to receive and support deploying units, the availability of prepositioned assets and other types of war reserve materiel, the establishment of resupply links from CONUS, and the capabilities of depot-level repair. VAS can help planners synthesize such complex and disparate information and relate it to the measure of greatest relevance—the sustainability of the combat force.

To a large degree, VAS applications in theater-level planning are the same as those in division- and corps-level planning. That is, VAS can be exercised against different scenarios to assess sustainability, compare asset allocation strategies, identify potential problems, and point the way toward actions to reduce weaknesses and improve robustness. In this last regard, however, theater-level planners have a wider selection of policies and options to consider, especially during deliberate planning. They might be concerned with the costs and benefits of alternative structural design concepts (e.g., SRAs or dedicated transportation systems), the merits of formal allocation and reallocation (i.e., cross-leveling) rules applied on a theaterwide basis, and the need for extensive deployment of depot-level resources (e.g., CONUS depot personnel, contractors, and specialized test equipment) into the theater during wartime.¹⁰ The flexibility and integrated perspective of VAS can help planners investigate complicated issues of this sort in an objective and systematic fashion.

¹⁰By way of illustration, a previous Arroyo Center study suggested that large gains in M1 tank availability could be achieved by modifying the theater support structure for certain high-tech components. Under one alternative, the projected gain within a single corps amounted to an additional 450 FMC tanks at the conclusion of a 120-day wartime scenario. The cost to obtain an equivalent result by boosting stock levels was estimated to be \$232 million as compared to a cost of less than \$40 million to implement the enhanced support structure. That research is reported in Berman et al., 1988. For a similar analysis involving the AH-64 helicopter, see M. L. Robbins, M. B. Berman, D. W. McIver, W. E. Mooz, and J. F. Schank, *Developing Robust Support Structures for High-Technology Subsystems: The AH-64 Apache Helicopter*, RAND, R-3678-A, forthcoming.

National-Level Applications

The potential users of VAS at the national level are a more diverse group than those in the field. Similarly, the range of applications at the national level is somewhat broader. We consider five areas in which VAS might be useful:

- Sustainment planning for contingency operations
- Development of support doctrine for the future Army
- Assessment of cost-reduction strategies and their implications
- Systematic reporting of unit sustainability
- Evaluation of the discrepancies between planned and actual performance.

Contingency planning. In the past, national-level organizations such as AMC were usually regarded as being remote from the combat force. Their wartime role was thought to be one of filling mass requisitions at the end of a long (in time, as well as distance) chain of supporting activities. Today, the realities of regional contingencies may be changing that perspective. In the case of limited operations in less-developed areas of the world, the Army may choose to minimize the deployment of logistics units and rely instead upon very responsive support from CONUS. Alternatively, the opposite may occur, and there may be a strong push to move national-level assets (e.g., depot repair capability) into the theater of operations. In either instance, the role of AMC and its MSCs could come to resemble "direct" support more closely than ever before.

A greater proximity to the combat force implies a greater need to participate in the sustainment planning process. AMC and its MSCs (and WSMs in particular) may wish to become better acquainted with such topics as planned optempos, weapon system availability goals, and field-level logistic resources and capabilities. With tools like VAS to help them interpret this sort of information, these organizations might develop a clearer picture of their potential for sustaining the force and the types of actions that could help them improve their day-to-day posture. Finally, since most contingencies cannot be expected to involve the entire combat force, VAS can help such users as WSMs and ODCSLOG to remain sensitive to overall status. When extraordinary actions are contemplated to support a contingency task force (e.g., radical changes in prioritization, diverting of assets, and extensive cross-leveling), VAS can provide early insights into the

effects on the sustainability of both the engaged and nonengaged forces.

Doctrinal development. The Army is currently in a state of flux with regard to such fundamental issues as its mission, size, and warfighting doctrine. In this uncertain environment, CASCOM is shaping the concepts and doctrine that will govern field-level logistic support in the future. Although much of this endeavor lies beyond the scope of VAS, planners at CASCOM might nevertheless benefit from adding it to their arsenal of tools. VAS can lend further quantitative weight to debates concerning the effect on sustainability of new structural arrangements (e.g., BMS); the advantages and disadvantages of widespread "stovepipe" initiatives (e.g., SRAs and special-purpose transportation systems); and the additional margin of performance offered by routine rather than intermittent use of controlled exchange, cross-leveling, and similar policies.

Cost-reduction strategies. The full array of strategies for reducing support costs are again beyond the scope of VAS. However, VAS can still be used to explore certain segments of this problem. A simple analysis might be to estimate the reduction in sustainability due to varying levels of cuts in Class IX inventories. Quantitative expressions of such tradeoffs are apt to be informative and helpful to key decisionmakers. To extend this case, VAS might also be used to assess tradeoffs among logistic resources. For instance, can large investments in spare parts be avoided by smaller investments in maintenance capacity or flexibility? What are the payoffs of expedited procurement mechanisms in terms of reduced procurement quantities? Can modest expenditures for dedicated transportation assets create more substantial savings in terms of reduced stockage of high-cost items? How would such tradeoffs affect the robustness of the logistics system?

Sustainability reporting. VAS gives planners the means to assess sustainability in a routine fashion. Its regular use could enable unit sustainability to be monitored and reported through the same channels (i.e., via MRSA and the RIDB) that are now used to transmit monthly unit readiness reports.¹¹ Ultimately, sustainability could play an equal role with readiness in determining a unit's C-rating under the Unit Status Reporting System.¹² The addition of a sus-

¹¹Of course, appropriate measurement criteria would first have to be established. This is a matter for further deliberation.

¹²The Air Force uses outputs from its Weapon System Management Information System (WSMIS) Sustainability Assessment Module (SAM) for this purpose. For a

tainability ranking would motivate logisticians to identify and correct problems beyond those made apparent through readiness deficiencies. WSMs or the MSC Readiness (*and Sustainability?*) Directorates could serve as focal points for coordinating such efforts. In addition, RIDB outputs could be augmented to include information (extracted from VAS) that would guide their activities.

Planned vs. actual performance. Many decisions concerning the future support of a weapon system are necessarily made early in its life cycle (often before production and fielding) and are performed based on very preliminary performance data. For example, inventory levels may be calculated and maintenance facilities sized according to engineering estimates of demand rates, maintenance task distributions (MTD), and repair times. Unsurprisingly, these data often turn out to be substantially different from later field experience. Too often, however, there is no attempt to update the data, revisit the original support concept, or determine the consequences of such discrepancies in terms of sustainability. VAS might help the PM or WSM to gauge the sensitivity of a support concept to future departures from initial planning assumptions. Subsequently, if monitoring of actual data reveals discrepancies beyond a certain tolerance level, logisticians can take steps to realign the support system accordingly.¹³

procedural description, see AF Regulation 55-15, *Unit Reporting of Resources and Training Status*, Headquarters, Department of the Air Force, Washington, D.C., November 1986. WSMIS/SAM incorporates an earlier version (since updated) of the Dyna-METRIC model embedded in VAS. See Dynamics Research Corporation, *WSMIS Sustainability Assessment Module (SAM, D087C) Functional Description, Appendix B*, Andover, Massachusetts, April 1991.

¹³This concept was originally proposed in R. Pyles and Lt. Col. R. Tripp, *Measuring and Managing Readiness: The Concept and Design of the Combat Support Capability Management System*, RAND, N-1840-AF, April 1982.

3. OPERATION OF THE VISION ASSESSMENT SYSTEM

In this section, we move from a conceptual discussion to an examination of some practical aspects of using VAS in sustainment planning. First, we present the rationale for operating VAS as a collection of similar but distinct modules tailored to the circumstances of their various users. Next, we describe the basic input-output structure of VAS and consider its place in the cycle of operations and logistics planning. Finally, we review its principal data requirements and describe some typical output reports.

THE ADVANTAGES OF MULTIPLE VAS MODULES

As outlined in Sec. 2, VAS has the potential to assist planners at echelons ranging from the division to the national level. However, responsibilities and perspectives—and hence, planning needs—can differ widely within this spectrum of users. For example, in comparison with organizations at higher echelons, a Division Materiel Management Center (DMMC) may have a relatively specific and short-term view of support requirements. Moreover, it may tend to focus upon the lower levels of the maintenance system (organizational and DS) and just one source of supply (the division's ASL). In contrast, a national-level WSM is likely to face issues that are less detailed but broader in scope. He must be concerned with all levels of maintenance (adding GS, depot, and contractor to the DMMC view) and multiple sources and categories of supply. He must also address a greater variety of support functions (e.g., transportation and procurement). Finally, the WSM is apt to be more interested in long-term structural design, support policy, and resource allocation strategies.

Given the diversity of its intended users and uses, the notion of VAS as a single, monolithic system has little intuitive appeal. We believe that the needs of planners would better be served by a limited set of variations, each based on the central VAS concept but equipped with features aimed at addressing a particular range of applications. This approach would allow a useful degree of specialization and eliminate the encumbrance of unneeded system capabilities.¹ Determining the

¹A similar design concept has been applied to a number of STAMISes (e.g., SAMS and SARSS).

ideal number of VAS variations is a matter for additional study, but a total of, say, three—corresponding to the division/corps, theater/MACOM/task force, and national levels—might come close to striking a reasonable balance between specialization and overproliferation.

Each VAS variation will be designed to support a specific group of users. In turn, each user will have his own module—in effect, a dedicated “copy” of VAS—to use as he wishes. Within AMC, for instance, the WSMs for the M1 tank and the AH-64 helicopter may have their own copies of the national-level variation of VAS. Operation of VAS in this decentralized, modular fashion recognizes the possible geographical and temporal dispersion of users. It will facilitate routine and informal planning activities. Individual planners will be able to structure assessments according to their own needs and assumptions, and to conduct analyses within the scope and time frames of their own choosing. VAS modules cannot remain completely independent of one another, however. Hierarchical linkages will be necessary to permit the passage of critical information needed to coordinate interechelon support. Moreover, there will be a common need among users for certain types of catalogue data (e.g., demand rates); limited centralization of such data may be appropriate.

BASIC STRUCTURE OF VAS

Although VAS variations and modules may differ somewhat in capabilities, all share the same basic structure in terms of classes of input data and output reports. As shown in Fig. 3.1, both operational and logistic sources are tapped to construct a VAS database.

Operational data originate with the mission statement and commander's guidance. Depending on the planning context, this data may reflect the contents of conceptual COAs, partially or fully developed OPLANs, or even actual operation orders (OPORDERs).² In the VISION framework, it will be a logistics command and control function to gather the data in raw form, interpret and quantify it in terms that can easily be related to demand for logistic resources, and

²These examples are drawn from a highly simplified view of operations planning. Typically, several alternative COAs are evaluated in terms of their respective strengths and limitations (accounting for both combat outcomes and supportability). The most promising is chosen as the basis for an OPLAN. The implementation of an OPLAN (sometimes preceded by last-minute reevaluation and modification) occurs in an OPORDER. Even after an operation commences, however, the need for ongoing assessment of sustainability remains.

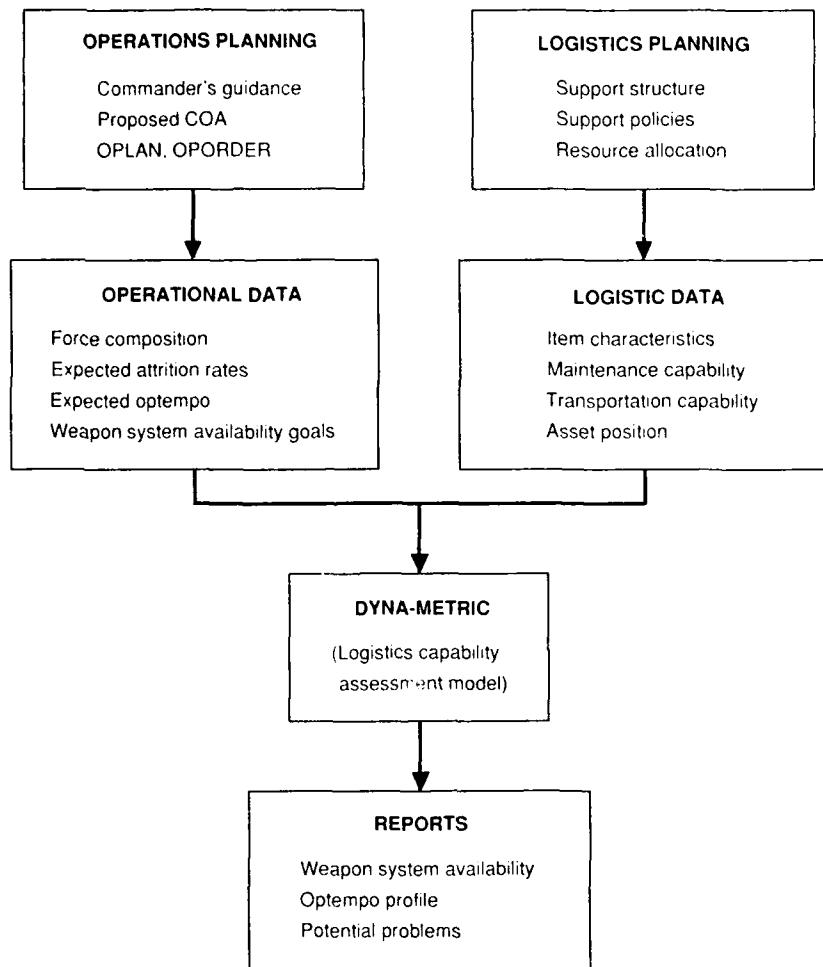


Fig. 3.1—Basic Structure of VAS

transmit it to all relevant VAS modules. Key operational data elements are the composition of the supported force, its expected attrition rates and optempos, and its weapon system availability goals.

A major objective of logistics planning is to identify the support concept—comprising structures, policies, and resources—that is best suited to sustaining the combat force in an uncertain future. VAS, of course, is intended to help planners assess and choose among different alternatives. The logistic data used by VAS are selected according to the particular concept under consideration. Some important

data elements include component failure characteristics, maintenance and transportation performance under the given structural and policy assumptions, and Class IX asset positions.

The two categories of data are used to drive Dyna-METRIC, a sophisticated logistics capability assessment model that projects future weapon system availability rates as a function of operational scenario and logistic resources.³ In addition to generating availability projections, Dyna-METRIC estimates the extent to which other operational goals (such as sustainment of planned optempos) can be supported. Moreover, it identifies potential performance-limiting problems in terms of the type, severity, and timing of resource shortfalls.

The input-output structure of VAS accommodates an iterative planning process, as depicted in Fig. 3.2. If operational plans and goals are projected to be supportable with a sufficiently high degree of confidence, the process may terminate immediately with acceptance (and, if appropriate, execution) of those plans. Otherwise, planners may begin to explore adaptive strategies aimed at redressing potential deficiencies. Clearly, the scope of such adaptations is governed by the situation at hand. In a peacetime, deliberate planning environment, it might be conceivable even to redesign fundamental logistics doctrine.⁴ In a time-sensitive setting, however, adaptations may be limited to such "quick and dirty" actions as cross-leveling critical assets, temporarily expanding maintenance or transportation capacity, or obtaining emergency assistance from neighboring or higher-echelon units. Note that it is also possible to conclude that a given COA or OPLAN is unsupportable by any means. This could lead to adaptations to the original operations concept; for instance, a planned attack could be scaled back to conserve resources or delayed to allow improvements in logistics posture.⁵ The effects of different adaptations may be represented by suitable modifications to the VAS database (e.g., adjusting asset positions, reducing certain maintenance or transportation times, or lowering planned optempos). Their consequences can then be assessed and compared through additional VAS runs. If necessary, these "what if" excursions could continue for many cycles.

³See App. B for a more detailed description of the Dyna-METRIC model.

⁴A good example is CASCOM's development of BMS in response to the strenuous demands associated with supporting ALB-F.

⁵A more extensive discussion of this interaction between operations and logistics planning may be found in S. C. Moore, J. P. Stucker, and J. F. Schank, *Wartime Roles and Capabilities for the Unified Logistics Staffs*, RAND, R-3716-JCS, forthcoming.

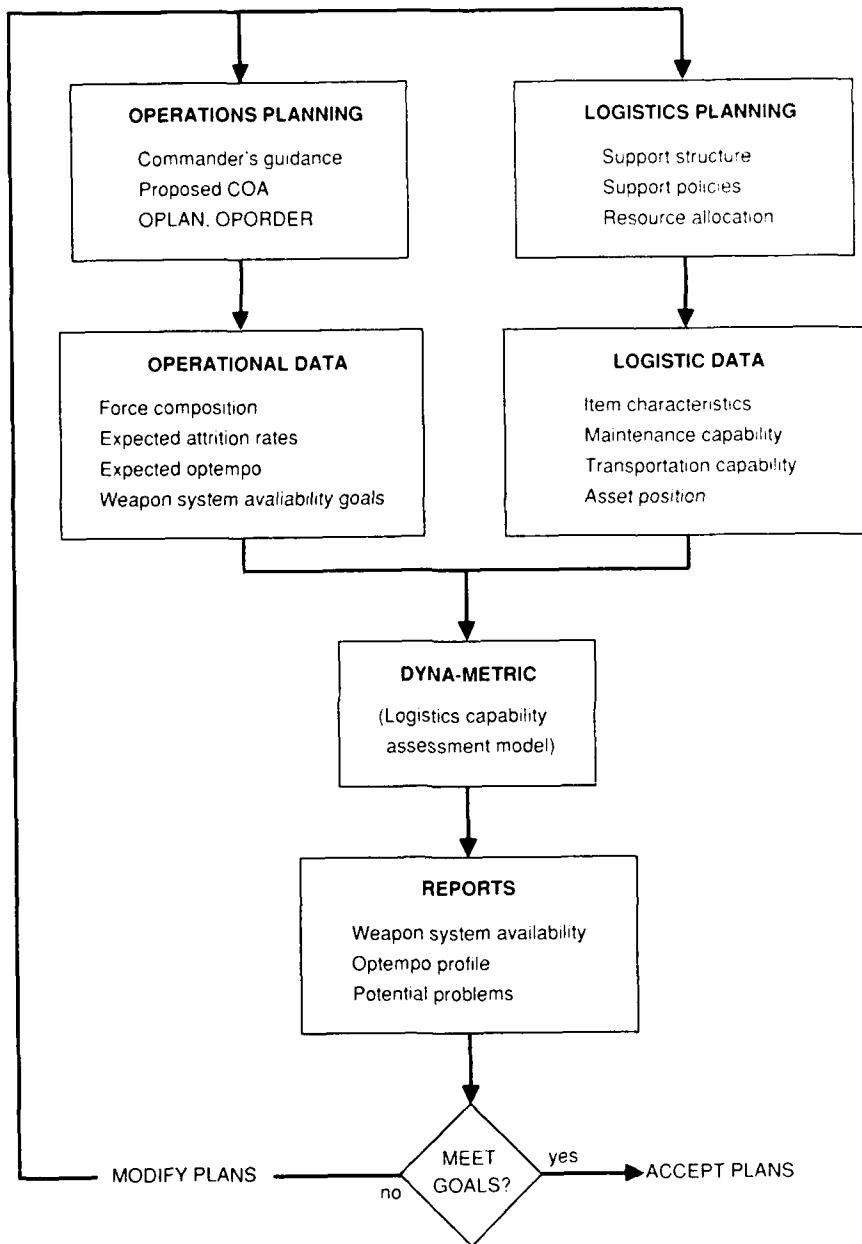


Fig. 3.2—Iterative Planning Process with VAS

DATA REQUIREMENTS

As indicated in the preceding discussion, VAS uses both operational and logistic data. Different variations modules may have different requirements in terms of scope (for instance, a division may not need to know about long-term theater war plans), but the general nature of the data is common to all modules.

Operational Data

VAS assumes that component demands occur in direct proportion to optempo (e.g., operating hours, miles driven, or rounds fired). Therefore, even though it does not directly address combat outcomes, VAS does require certain types of information about the combat force in order to compute its expected support needs. The following items of operational data are used:

- Force composition
- Expected attrition rates
- Expected combat postures or optempos
- Weapon system availability goals.

These quantities may be constant or may vary over time; in the latter case, their values must be specified over the entire course of the scenario in question.

The composition of a force refers to the number of weapon systems assigned to it (M1, M2, AH-64, etc.) and to the number (or density) of end items of each kind. Planned mid-scenario changes (for instance, those due to the arrival of reinforcements or to disengagement by a part of the force) can be reflected.

Changes in force composition resulting from attrition losses are handled explicitly by the model. Loss rates are expressed as a percentage of the remaining force per day. In the event that replacements are held in reserve (i.e., "fillers"), loss rates may be set equal to zero for that portion of the scenario during which replacements are expected to remain available.

For planning purposes, it is assumed that a particular combat posture (e.g., light static defense) equates to a fixed optempo (e.g., eight rounds fired per tank per day); hence, either form of input is acceptable. A simple table look-up scheme can be used to store the mapping between combat postures and optempos.

Weapon system availability goals serve two purposes. First, they are used as yardsticks against which to measure projected performance; for instance, VAS may report that expected M1 availability at the end of five days is such that there is only an 18 percent chance of meeting a goal of 85 percent availability. Second, they form the criteria for identifying "problem" components—that is, those whose projected supply postures seem inadequate to support a specified level of performance. In general, as goals becomes more stringent, it becomes more likely that any given component will constitute a potential problem.

Operational data may be specified at whatever level of aggregation the user wishes. A divisional planner, for example, may choose to treat the entire division as a single unit, with, say, 348 tanks all subject to an average attrition rate and maintaining an average optempo. Alternatively, he may increase the level of resolution by breaking the division down into brigade- or battalion-sized (or even smaller) units, each with its own operational characteristics. Figure 3.3 shows sample operational data (which can subsequently be processed into an output report showing the division's total optempo profile) for a typical armored division's M1 force over a five-day scenario. Note that the attrition rates imply the availability of replacements sufficient to offset attrition losses for the first two days; also, note that the second brigade is augmented by a fresh battalion on day 4.

Logistic Data

The logistic data used by VAS are considerably more extensive and detailed than the operational data described above. Logistic data may be divided into three major categories:

- Catalogue data (chiefly component characteristics)
- Performance characteristics of major logistic functions
- Current asset positions.

The attributes of weapon system components are defined in a diverse set of catalogue data. The full set used by VAS is documented in publications about Dyna-METRIC.⁶ Some of the more significant items

⁶See K. E. Isaacson, P. Boren, C. Tsai, and R. Pyles, *Dyna-METRIC Version 4: Modeling Worldwide Logistics Support of Aircraft Components*, RAND, R-3389-AF, May 1988, and K. E. Isaacson and P. Boren, *Dyna-METRIC Version 5: A Capability Assessment Model Including Constrained Repair and Management Adaptations*, RAND, R-3612-AF, August 1988.

Scenario		Sample				
Unit		th Armored Division				
Weapon system		M1 tank				
		Day				
End item densities	1	2	3	4	5	
	1st Bde	116	116	116	116	116
	2nd Bde	116	116	116	174	174
Attrition rates	3rd Bde	116	116	116	116	116
	1	2	3	4	5	
	1st Bde	00	00	06	05	05
Optempo (daily rates)	2nd Bde	00	00	10	08	07
	3rd Bde	00	00	02	02	02
	1	2	3	4	5	
Availability goals (FMC %)	1st Bde miles driven	5	5	15	15	12
	rounds fired	10	10	30	20	20
	2nd Bde miles driven	6	6	10	15	8
Optempo (daily rates)	rounds fired	15	15	30	30	15
	3rd Bde miles driven	10	12	5	5	5
	rounds fired	20	25	10	10	10
Availability goals (FMC %)	1	2	3	4	5	
	1st Bde	70	70	95	90	85
	2nd Bde	90	90	95	95	90
Availability goals (FMC %)	3rd Bde	95	95	65	65	70
	1	2	3	4	5	

Fig. 3.3—Sample Operational Data

are discussed here. The most basic data identify components by such means as National Stock Number (NSN), nomenclature, part number, and special-purpose maintenance codes. Indenture data specify the "parent-child" relationships among components and include the quan-

ity of each type of component installed in its next higher assembly.⁷ The component demand process is characterized by data that include peacetime and wartime demand rates, an indicator of the mode of failure (e.g., operating hours, miles driven, or rounds fired), and a measure of demand rate variability (the variance-to-mean ratio, or VTMR). The proportions of failed components that are repaired at different echelons (i.e., the MTD) may also be specified; so too may the rates at which they are disposed of (declared irreparable and discarded). Component-dependent processing times in various logistics functions are described by such data as repair time at each echelon and procurement lead time at the national level.

Maintenance and transportation are the primary logistics functions that possess performance characteristics independent of component identity. Maintenance data include the type and quantity of repair resources (whether personnel or test equipment) at each location, their assigned workloads, their level of availability throughout the scenario, and the extent to which they can operate in degraded modes of capability. At present, transportation performance is described simply as a set of time lags between locations within the logistics system. However, as enhanced representations of transportation are developed, it should be possible to use such data as the quantity and speed of transportation resources and the capacities of individual links in the network.

Current LRU and SRU asset positions (e.g., the number that are serviceable, in repair, and on order) fit within the category of component characteristics, but are discussed separately because they are a far more unstable variety of data. That is, they are subject to change on a continual basis and may fluctuate wildly within a short span of time (unlike demand rates, for instance, which typically reflect long-term averages and are updated infrequently). Accurate information about asset positions is especially crucial in time-sensitive planning and assessment because it is the most relevant descriptor of current supply posture. Obviously, it is of less concern in deliberate planning, which tends to use notional representations of distant scenarios and conditions.

⁷Line Replaceable Units (LRUs) are major components that are indentured to (i.e., directly removable from) the weapon system. Shop Replaceable Units (SRUs) are subcomponents indentured to LRUs. Below SRUs are "bit and piece" parts.

OUTPUT REPORTS

VAS generates a large volume of information which can be manipulated and displayed in different ways. Its principal outputs describe projected weapon system availability over the course of the scenario and identify those components that are most likely to obstruct the achievement of specified availability goals.

Figure 3.4 shows a sample weapon system availability report for the M1 force of a typical armored brigade over a five-day wartime scenario. Availability is expressed in terms of the expected percentage of the force that will be FMC at the end of each day (represented by the solid line). Changes in projected availability over time result from the complex interaction of all of the factors discussed above—operational activity, supply posture, the performance of different logistics functions, and so forth. The decline over the first four days, for instance, might be traced to extremely demanding optempos or inadequate ini-

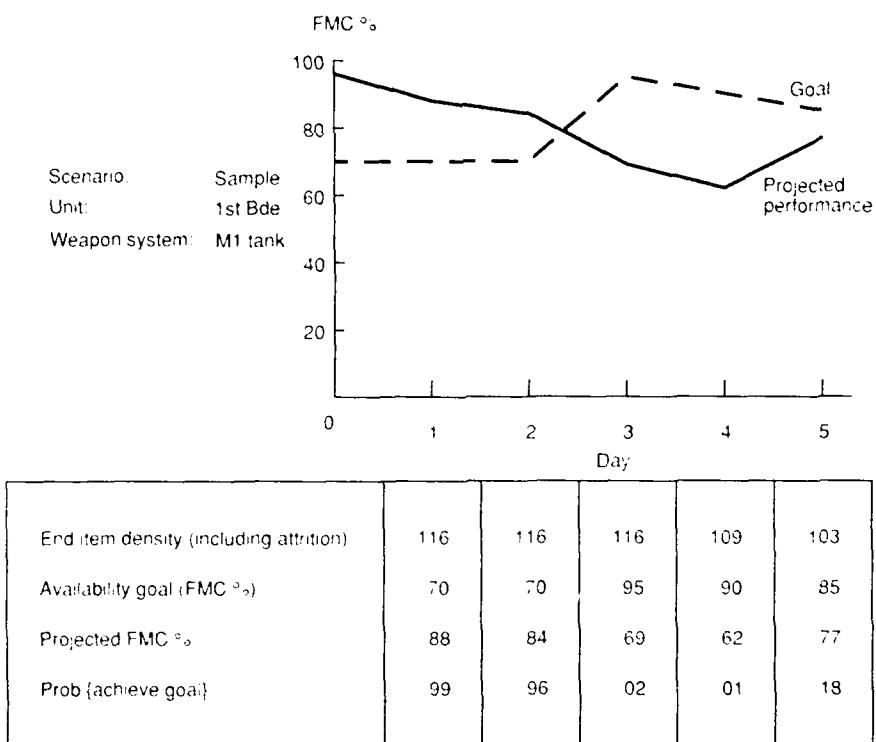


Fig. 3.4—Sample Weapon System Availability Report

tial spares. Similarly, the rise on day 5 might be due to special recovery measures or the arrival of fresh supplies.

Note that availability goals may also change over time (see the broken line in Fig. 3.4), reflecting different sustainment objectives as the scenario progresses. The probability of achieving the goal on each day is determined by the probability distribution of FMC tanks. On day 5, for example, the expectation is that M1 availability will fall short of the goal by 8 percent (an expected value of 77 percent against a goal of 85 percent); however, because of statistical variation around that expected value, there is an 18 percent chance that actual availability will equal or exceed the goal.

If projected availability falls unacceptably far below the goal, planners need to be able to identify the underlying problems. VAS produces a ranked list of problem components for each day of a scenario, as shown in Fig. 3.5. This list corresponds to day 4 of the scenario depicted in Fig. 3.4. As indicated in the upper right-hand corner of Fig. 3.5, the availability goal for day 4 is 98 FMC tanks (90 percent of the remaining total of 109 tanks); alternatively, this can be expressed as 11 (or fewer) non-FMC (NFMC, or deadlined) tanks. The listed components are those whose expected supply postures on day 4 have a high probability of causing more than 11 tanks to be deadlined. Each component is identified by NSN and nomenclature. Also specified are its primary repair resource (in this example, the Direct Support Electrical Systems Test Set (DSESTS) and Thermal Systems Test Set (TSTS) are shown); the quantity of assets in different *pipelines*, or stages of processing (e.g., in repair, in transit, or on order); and the total pipeline quantity; and the requisitioning objective (RO, or stockage level) of the unit's ASL.⁸ The rightmost column reports the expected number of deadlined tanks attributable to each component's supply status. For example, 26 tanks (vs. a goal of 11) are expected to be deadlined on day 4 because of missing turret networks boxes. Note that an item may appear on this list even if the expected number of tanks that it will deadline is below the goal. The thermal receiver unit of the thermal imaging system (TIS-TRU), for instance, is expected to deadline only 9 tanks; however, by the nature of its pipeline probability distribution, there is a significant likelihood that it could in fact deadline 11 or more tanks.

⁸As our example concerns a brigade, RO applies to the "slice" of the divisional ASL allocated to the brigade.

Scenario:	Sample	Day of scenario:	4
Unit:	1st Bde	Availability goal (number FMC):	98
Weapon System:	M1 tank	Expected number FMC:	68

NSN	Nomenclature	Repair Center	Expected Pipeline Quantity				ASL	
			Repair	Transit	Order	Total	RO	E(NFMC)
1015-01-076-6688	Turr Net Box	DSESTS	15	4	17	36	10	26
5975-01-083-9872	Elec Cont Unit	DSESTS	12	6	10	28	6	22
1240-01-074-8946	TIS-ICU	TSTS	8	7	10	25	3	22
6110-01-083-5606	Hull Net Box	DSESTS	13	5	14	32	19	13
1240-01-074-8947	TIS-TRU	TSTS	6	3	5	14	5	9

Fig. 3.5—Sample Problem Components Report

In addition to identifying potential problems, this report gives planners a sense of problem magnitude and may even suggest strategies for overcoming them. The most straightforward approach is always to obtain more spares. In the present example, an increment of 15 turret networks boxes (26 less the NFMC goal of 11) would bring the expected number of tanks deadline for that reason near to the desired goal. Of course, additional assets would probably be needed to provide enough of a safety margin to allow the turret networks box to be dropped from the list entirely. Alternatively, it might be noted that three of the five problem components are repaired on the DSESTS and have large repair pipelines. Planners might surmise that an increase in DSESTS capacity would ease their supply shortfalls; the benefits of such adaptations as adding another test set or setting up an extra work shift could then be assessed by modifying the original VAS database and running Dyna-METRIC anew.

4. IMPLEMENTATION ISSUES

Before the Army can consider formal, full-scale implementation of VAS, three fundamental questions must be addressed:

- Is VAS feasible from the standpoint of data requirements and methodology?
- Does VAS offer benefits that outweigh its expected costs?
- Those benefits aside, is VAS sufficiently usable that planners throughout the Army will actually use it?

Clearly, if the answer to any one of these questions is strictly negative, the VAS concept should be either revised or discarded. On the other hand, if all three can be answered affirmatively, a persuasive case will have been made for moving forward.

In this section, we discuss several key issues pertaining to the topics of feasibility, costs vs. benefits, and system usability. Our intent is to highlight specific areas that call for further study and clarification. However, we believe that certain initial steps in an incremental development plan (e.g., the construction of limited prototypes) need not—and should not—await definitive results. Indeed, such exploratory efforts are often integral to the discovery process.

FEASIBILITY

The VAS concept represents a significant extension of the current system's approach to measuring equipment readiness and sustainability. As such, it warrants careful scrutiny to determine whether it is feasible—that is, whether it can function properly within the overall framework of Army information systems. Two aspects of VAS that especially distinguish it from the current system are its consumption of a relatively wide variety of data and its use of a somewhat unfamiliar methodology.¹ The availability and accessibility of those data and the suitability of the Dyna-METRIC model form the basis for the following discussion of feasibility.

¹Unfamiliar, that is, to the general Army logistics community. The Dyna-METRIC model has a history of successful applications in Air Force logistics management. In recent years, newer versions of Dyna-METRIC have been used to examine Army issues as well, both by in-house Army organizations and by RAND's Arroyo Center. See App. B for further details of these studies.

Data Availability

As outlined in Sec. 1, current methods for measuring and reporting equipment readiness depend only upon direct observation (e.g., of numbers of end items on hand, historical mission capability rates, and identities of deadlining components). In contrast, VAS, which attempts to project sustainability in future scenarios, requires a broad array of descriptive operational and logistic data. Although these data needs far exceed those of the readiness reporting system, they are not unduly burdensome when examined in light of other Army systems and models. For example, SESAME uses similar data to generate stockage lists and compute requisitioning objectives.² Likewise, the portion of TLRS devoted to Class IX analysis draws upon an extensive and detailed database.³

It is somewhat reassuring that in terms of data needs, VAS is "in the ballpark" with respect to existing models. However, for the sake of completeness, it will still be necessary to identify potential sources (or a lack thereof) for each VAS data element. Such an exercise will undoubtedly give rise to questions pertaining to data availability. One of the most fundamental of these is how to acquire data that do not presently exist. Are there channels through which such data could reasonably be collected? Would those collection efforts be feasible in terms of processing and communications requirements? Will the data be sufficiently interesting and valuable that they should be incorporated into a STAMIS, or should they be handled off-line? From the standpoint of VAS, an obvious example of a current data deficiency is the optempo parameter that plays a key role in translating planned operational activities into demands for logistic resources. One possible avenue for gathering and transmitting optempo data may be the Combat Service Support Control System (CSSCS) component of the Army Tactical Command and Control System (ATCCS).⁴ Other approaches will also be considered in the VISION concept relating to logistics command and control.

In some instances, data needed by VAS clearly exist but can be found only in rudimentary form. For example, MTD parameters are needed to properly represent the flow of unserviceables in a multi-echelon maintenance structure. At present, these data are not collected explicitly, although they can easily be inferred from maintenance

²See *SESAME 88 User's Guide*, U.S. Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, Maryland, May 1988.

³*Total Logistics Readiness and Sustainability 1991 (TLRS 91)*.

⁴*Combat Service Support Automation Architecture*

records input to SAMS or recorded by Sample Data Collection (SDC) efforts.⁵ If VAS is to be implemented, new collection and processing procedures must also be adopted to provide MTD and similar types of data.

Another important issue concerns data validity. While the nature of uncertainty is such that no data can be regarded as infallible, there are some cases where data are so clearly suspect that they cannot reasonably be used. Again, MTD provides a good illustration. These parameters *do* exist in current STAMISes; however, the majority have never been updated from the initial engineering estimates found in the Provisioning Master Record (PMR). In light of equipment maturation and possible changes in maintenance doctrine and capabilities, these estimates might now differ substantially from actual field experience. A more controversial example has to do with asset visibility. It is widely believed within the national-level materiel management community that systems such as the Selective Item Management System-Extended (SIMS-X) are routinely inaccurate. Whatever the source, it is essential that such shortcomings be resolved in ongoing or planned STAMIS modernization programs.⁶ Otherwise, the same doubts that afflict the data will naturally extend to any assessments that those data support.

A final issue relates to possible complications due to *too much* data availability. A single data element often has multiple sources, each containing a different value. Thus, a component's apparent failure factor may depend upon whether it is extracted from the National Stock Number Master Data Record (NSNMDR) or from a Field Exercise Data Collection (FEDC) or SDC database. Similarly, component repair time may vary as a function of the reporting channel. In some cases, even large differences may be readily understandable; for example, NSNMDR failure factors are worldwide averages, whereas the corresponding FEDC or SDC factors may reflect environmental or geographical biases. In other cases, the rationale for differences may be far more obscure. Should any one source be preferred? If so, how should that selection be made? And if not, how should differences be reconciled?⁷

⁵MRSA's Work Order Logistics File (WOLF) archives SAMS records for at least two years and could be the most convenient source for a retrospective examination of MTD. See *Work Order Logistics File (WOLF) User's Manual*, USAMC Materiel Readiness Support Activity, Lexington, Kentucky, December 1989.

⁶For instance, SLA's TAV initiative is a positive step toward improved systemwide asset visibility.

⁷One of the most useful features of MRSA's Automated Data Validation and Netting Capability Establishment (ADVANCE) system is its ability to provide simultaneous

Data Accessibility

In some VAS applications—for example, long-term, in-depth analyses of competing structural and policy alternatives—logisticians may enjoy the luxury of slowly assembling the appropriate databases. However, VAS is also intended to support sustainment planning and assessment on a routine and continuing basis. Here, it is not enough merely to confirm that the data exist; we must also be satisfied that they are accessible within the time limits imposed by the planning process.

Because STAMISes are not designed with VAS applications in mind, database assembly is likely to be complicated by the need to tap a large number of sources. Moreover, some data elements are extremely fluid (e.g., wartime optempo parameters and asset balances) and demand constant reexamination. To be effective, VAS must include mechanisms that allow critical data to be collected, processed, transmitted, and updated in a timely fashion and in accordance with the needs of individual users. Each of these steps should be defined in terms of its required frequency, its responsible agent, and the nature of its interface with adjoining steps.

Consideration of data accessibility naturally raises the issue of STAMIS architecture. Should VAS rely upon large, central data systems? Or would a distributed database approach featuring smaller, local stations be more workable?⁸ Is the formal structure of a STAMIS a prerequisite for data accessibility? Are there any conditions under which it would be preferable to operate VAS using non-standard data sources? Or must even VAS-unique data ultimately be embedded within some STAMIS? It is important and worthwhile to address these questions at an early stage of VAS development; otherwise, any future move toward implementation may be hampered by the absence of viable data input.

Finally, we note that accessibility is a concern not just in terms of input data, but also in terms of system outputs. In a complex, multi-echelon support environment, one unit's assessment outcomes may—

access to many alternative data sources. This ability enables logisticians to compare values and assess the relative merits of each source. See ARINC Research Corporation, *Functional Description for the Army Data Validation and Netting Capability Establishment Program*, February 1988. ADVANCE has since evolved into the Weapon System Management Analysis System.

⁸Good examples of the distributed database approach include MRSA's ADVANCE and also the U.S. Army Tank-Automotive Command's Fielded Vehicle Performance Data System (FVPDS). FVPDS is described in *Fielded Vehicle Performance Data System (FVPDS) Functional Definition Report*, U.S. Army Tank-Automotive Command, Warren, Michigan, May 1988.

and in fact, should—prompt others to take actions (or avoid actions) that will affect its resources and projected sustainability. Therefore, it is essential to determine whether such information can be passed expeditiously and to identify those parties who should receive it.

Suitability of the Dyna-METRIC Model

Hand in hand with the data goes the vehicle by which those data are interpreted to yield projections of sustainability and indications of potential future problems. In the case of VAS, that vehicle is the Dyna-METRIC model. It is important to observe at the outset that Dyna-METRIC is by no means an ultimate model. It is certainly more limited in scope than, say, TLRS.⁹ It is primarily oriented toward Class IX sustainment/resupply as opposed to readiness/deployment, reconstitution, or redeployment. Thus, there clearly is room in an extended VAS concept for other models that focus on other aspects of logistics. Such expansion, whether in the framework of VAS or in an even larger construct, is to be encouraged.

Considerations of model scope aside, there are technical elements of Dyna-METRIC that warrant closer examination. For instance, does it adequately reflect the key characteristics of Army logistics policies, processes, and functions? Does it represent enough of the interaction between the Army's multiple echelons of logistic activity? We believe that as the model now stands, the answer to these questions is a qualified affirmative. Certainly, there is evidence to support this position, both from Army evaluators and from extensive research experience with Dyna-METRIC at RAND's Arroyo Center.¹⁰

However, it is also apparent that there is room for improvement. Additional work should be undertaken to treat the effects of uncertainty and the role of management adaptation in forging a more flexible and robust support system. Some initiatives, such as explicit modeling of battle damage and repair, are already under way. We expect that quite apart from the evolution of associated data systems, the development of VAS will be marked by continual refinement of Dyna-METRIC. Of course, if VAS implementation becomes a reality, it will be necessary to establish procedures governing software verification and configuration control.

⁹Of course, it is also intended to be more generally accessible and better suited to routine planning and assessment.

¹⁰See App. B for references.

COSTS VS. BENEFITS

In a climate of limited resources, consideration of costs and benefits naturally takes precedence in determining whether to implement a new initiative such as VAS. Therefore, it will be necessary to develop appropriate techniques for estimating and quantifying these factors. With such information, VAS will be able to find its place in the budgeting process and compete for funding with other programs aimed at improving combat capability.

Costs

Estimating the costs associated with VAS is complicated by the fact that most supporting STAMISes have been (or are being) developed with other applications in mind. To some degree, then, investments in STAMIS modernization can be viewed as sunk costs from the standpoint of VAS. Even so, any implementation effort will surely incur direct costs related to VAS-specific data collection and processing capabilities, augmentation of data links, and other STAMIS modifications and upgrades.

In addition to data systems, major contributors to total cost will include hardware acquisition, software engineering, user training, and other activities arising from the design, development, operation, and maintenance of VAS. Such costs cannot be predicted with certainty, but useful estimates can probably be derived from past experience with comparable systems or through standard industry cost models.¹¹ Limited prototyping might also provide rough indicators of cost.

Benefits

In contrast to requirements- or execution-oriented systems like SESAME or the Readiness-Based Maintenance System (RBMS), VAS does not of itself generate explicit decisions (e.g., to buy ten widgets and twenty gizmos, or to distribute five widgets to one division and only one to another). Rather, it serves as a decision *support* tool for planners to use in assessing the implications of different strategies. Its greatest value lies in helping planners to make rational choices on the basis of such relevant criteria as cost and sustainability.

¹¹The Air Force's experience with WSMIS SAM would be a relevant case for comparison. For other ideas, see B. W. Boehm, *Software Engineering Economics*, Prentice-Hall, Englewood Cliffs, New Jersey, 1981.

It is often difficult to fully separate actual decisions from the tools used to help make them. For this reason, it is also difficult to attribute specific, quantitative benefits to VAS. Some might argue that it is only the decisions themselves that can produce calculable benefits. However, in complex, uncertain, and pressured environments, there are no guarantees that unassisted planners will always choose a good strategy, much less the best of many alternatives. For instance, planners might be asked to quickly identify the most cost-effective way to support a contingency force in an austere theater of operations. Where should resources be focused? On faster transportation? Forward positioning of depot-level repair capability? Improved information and execution systems to allow better control of scarce assets? By how much can each strategy be expected to increase overall sustainability? How do they interact? Are they mutually reinforcing, or are they redundant? Is a mixed strategy preferable? What are the anticipated consequences for the total force? In the face of such questions, intuition alone may fall short. Surely, a capable decision support system must count for something here.

A satisfactory approach for isolating and quantifying the benefits of VAS is a matter for further research. Again, prototyping may provide a useful vehicle for conducting such examinations. VAS might be able to show certain strategies to be significantly more or less advantageous than expected; this would indicate its capacity for steering planners in the right direction and would be to its credit. Qualitative evidence should also be weighed. If VAS outcomes are uniformly transparent to planners, its potential value would clearly be diminished. If, however, planners are routinely confronted by difficult choices and feel that they lack the means either to decide or to justify their decisions, such testimony would further substantiate the benefits of VAS.

Tradeoffs

Any eventual implementation plan must resolve certain tradeoffs between costs and benefits. One such tradeoff concerns the range of items to be included within VAS. Obviously, coverage of all Class IX items would be extremely data-intensive and time-consuming, and it might also entail large increases in STAMIS operating costs. If an appropriate subset of items were to be considered instead, it is possible that much of the benefit due to VAS could still be achieved. Some reasonable criteria for inclusion are mission essentiality, high unit cost, high volume of demand, and existing designation as a selectively

managed item.¹² In any case, these items will have to be coded for automatic selection, processing, and incorporation into VAS databases.

Another tradeoff involves the scope of implementation. For instance, VAS may be judged worthwhile and implemented at echelons above corps (EAC) but not at corps level or below. Or, its use may be limited to, say, the Active Army and not the Reserve or National Guard.¹³ Whether partial implementation is an initial step or a desired end, it can be accomplished more easily because of the modular approach to VAS operation described in Sec. 3.

USABILITY

If VAS is to be a viable tool for planners, it must be usable within the constraints imposed by the planning process. Not only must it address relevant questions and produce meaningful output, but it must do so in a convenient and timely manner. In the following discussion of usability, we focus on three major issues: the capabilities that should be built into different VAS modules, the nature of the interface between VAS and its various users, and the robustness of the system in the presence of real-world operating limitations.

Capabilities of Different Modules

In Sec. 3, we advocated the development of a small number of VAS variations, each sharing the same basic structure but composed of a unique set of capabilities and features. Furthermore, we proposed that VAS be operated as a collection of user-based modules—each matching a particular variation—rather than as a single, large system. Much of the rationale for this concept stems from the fact that different users have different planning and assessment needs and may require the flexibility to work independently as well as cooperatively.

The argument in favor of multiple variations and modules presumes that worthwhile gains can be achieved by equipping VAS users with no more capabilities than are needed to perform their missions. For example, a DMMC module might not need to reflect every echelon of

¹²Selectively managed items (SMI) are, for a variety of causes, subjected to particularly close scrutiny within the materiel management community.

¹³A similar distinction exists under the current readiness reporting system. Active Army units report monthly, whereas Reserve and National Guard units report quarterly. See AR 700-138.

the logistics system. By simplifying its structure, it should be possible to reduce operating complexity, eliminate extraneous data requirements, and improve processing speed. However, this approach does involve some tradeoffs. Multiple variations imply higher development costs and more difficulty in maintaining configuration control and instituting upgrades and modifications. Further investigation is needed to determine an appropriate number of variations and an effective distribution of capabilities. The primary consideration here should be the types of questions faced by planners in each part of the system.

User Interfaces

The version of the Dyna-METRIC model to be adapted for Army applications (including VAS) remains very much an analyst's tool today. It is suitable for research purposes, but it is not yet "user friendly" enough for routine access by a large community. For instance, data input is rigidly formatted, important results often lie deeply buried in printouts, there is little in the way of graphical displays, and substantial effort may be required to match related bits of information.¹⁴ Such shortcomings can impair a planner's ability to conduct rapid assessments and "what if" analyses of potential problem-solving strategies.

The foregoing criticism is not aimed at the content of Dyna-METRIC; it merely underscores the need for more effective interfaces for handling input and output. If VAS is to become an everyday tool, it must offer more flexible and interactive methods for assembling and modifying its database; likewise, it must produce outputs that are quickly and easily comprehensible and that can be rearranged and examined from different perspectives. Attention should be given to the development of preprocessors and postprocessors and integration with spreadsheets, graphics packages, and so forth. These can simplify the planner's tasks and enable him to spend more time analyzing problems and thinking of solutions. In the longer term, it might also become feasible to employ expert systems to help planners interpret outputs.

¹⁴The Air Force version of Dyna-METRIC incorporated into WSMIS SAM has undergone numerous modifications to improve its usability.

Sensitivity to Real-World Problems

Operation in the real world will undoubtedly expose VAS to hardships that have not been fully considered in the current conceptual setting. Data mishaps are a good example. Even if STAMISes increase markedly in capability, problems are sure to occur—especially under the stressful, chaotic conditions of war. Systems will fail or be overloaded, data will contain errors or be delayed or lost outright, and the quality of assessments will suffer in consequence. How sensitive will VAS be under such circumstances? Will even a small amount of confusion invalidate its results? Or will its performance degrade more gracefully? There is no firm basis for predicting the answers to these questions, although it is likely that useful insights can be obtained through prototyping.

Because data problems can never be wholly eliminated, it remains worthwhile to explore ways to counter their effects. In connection with VAS, it may be possible to develop automated procedures to highlight data elements that appear implausible. Similar mechanisms could be used to estimate or extrapolate values for missing data. Here, too, there may be a role for an expert systems approach.

5. RECOMMENDATIONS

If it can be fully realized, VAS will significantly expand the arsenal of tools available to logistics planners. It will complement the equipment readiness reporting system by also providing planners with forward-looking, weapon system-oriented assessments of sustainability. Just as readiness reporting highlights existing problems, VAS will help to identify potential future problems, ideally while still in the early stages of the planning process. Even more important, VAS will enable planners to evaluate different strategies for avoiding or minimizing those problems. Such strategies may range from ad hoc methods for redressing a local supply shortfall to systemwide policies aimed at reducing costs or enhancing sustainability in general.

As appealing as the VAS concept may be, the path leading to its realization is not yet clear. In Sec. 4, we considered a variety of open issues related to system implementation. In this section, we propose an approach to resolving some of those issues in preparation for further development.

THE RATIONALE FOR PROTOTYPING

Earlier, we identified three criteria (feasibility, benefits that outweigh costs, and usability) that must be satisfied before full implementation of VAS can logically commence. Although it might be reasonable to suppose that all three can eventually be satisfied, it cannot be said that any one has already been so. Feasibility, for example, hinges to a large extent upon the continued evolution of STAMISes; even where data exist, some needed processing and transmission capabilities have yet to be completely designed or proven. Estimation techniques for both benefits and costs must also be explored and refined before VAS can be justified in financial terms. Finally, system usability must be improved in several ways. Some (e.g., integration with graphics and spreadsheet packages) are relatively straightforward, but others (e.g., setting the capabilities of different VAS modules or reducing sensitivity to faulty data) are more problematical.

The potential costs of VAS are not so small nor its probable effects so limited that the Army can reasonably proceed without further attention to these criteria. At the same time, the answers to a number of relevant questions (e.g., Where do STAMISes currently fall short? What benefits are available? How can the system be tailored for

maximum usability by planners?) seem more likely to emerge from practical experience than pure conjecture. We believe that the obvious solution is to build and operate prototypes of VAS specifically to address issues pertaining to full implementation.

Although it is certainly less ambitious than a direct plunge into implementation, prototyping offers several notable advantages. First, it provides a controlled setting in which to investigate system performance. Here, unexpected flaws and problems can be uncovered without unduly disrupting the smooth conduct of everyday business. Second, prototyping allows further (and possibly, concurrent) refinement of both concept and methodology before the Army invests too heavily or becomes overly committed to a particular course. It allows more extensive exploration of the role of VAS in the planning process and greater clarification of the needs of planners. It also allows more opportunity to identify data gaps and expose unforeseen conflicts with existing policies and procedures. Third, prototyping has the potential to yield significant savings in overall development costs. Because it is by nature more limited than full implementation, problems encountered during prototyping are likely to be better contained and easier (and less expensive) to correct. Finally, the experience that the Army will acquire during prototyping will undoubtedly serve it in good stead in any future implementation effort.

AN INCREMENTAL APPROACH TO PROTOTYPING

The issues to be addressed by prototyping do not all share the same degree of immediacy. For example, data availability requires prompt attention because it is so closely dependent upon ongoing STAMIS development. If shortcomings are to be redressed through STAMIS upgrades or modifications, these must be identified quickly to protect against long lead times. User interface improvements are no less important, but these will largely be internal to VAS and could also exploit off-the-shelf software. Therefore, consideration of this issue may be less urgent.

In view of such distinctions, we suggest an approach based on a sequence of prototypes that expand incrementally in scope. Each prototype should shed new light on the three criteria for implementation, but within this broad objective, each may have a different emphasis. For instance, one prototype may focus primarily upon feasibility, another on costs and benefits, and a third on usability. Multiple prototypes also allow a more thorough examination of the different users and uses of VAS. Thus, one prototype may address deliberate planning at the national level while another concentrates on time-sensi-

tive planning at corps or division level. A variety of weapon systems can also be covered in such an approach.

We propose two or three phases of prototyping, with progressively more ambitious goals and a closer resemblance to real-world planning. The first phase should be conducted mainly for demonstration purposes. It should take place off-line (say, at RAND) and should not necessarily attempt to replicate real-time conditions. Data should be drawn from STAMISes when possible, but where it is lacking, non-standard sources or even reasonable assumptions should be used. Some key goals for this demonstration prototype, in approximate order of emphasis, are to:

- Illustrate the range of VAS applications at two separate echelons (perhaps the national and corps levels) using case studies to address different planning questions
- Evaluate data availability, identify shortcomings, and suggest STAMIS improvements
- Prepare an initial list of user interface enhancements that might make VAS more accessible to the general planning community
- Suggest methodological improvements (to Dyna-METRIC)
- Gather qualitative assessments of VAS benefits by exposing the results of this prototype to Army planners.

The second phase of prototyping should begin to subject VAS to the pressures of everyday operation. This operational prototype should be placed in the hands of a select group of Army planners to determine whether VAS can become a valuable tool. Real-world constraints should be recognized here. The operational prototype should include the development and testing of links between STAMISes and VAS. However, reasonable exemptions should be allowed; for example, if a needed STAMIS feature remains in development, temporary workarounds should be used. The goals of this prototype are to:

- Evaluate data accessibility, identify shortcomings, and suggest STAMIS improvements
- Incorporate a variety of user interface tools and evaluate their contributions to increased usability

- Design and conduct an exercise to validate VAS outcomes against real, measurable data¹
- Begin to assemble cost data and develop techniques for quantifying benefits
- Evaluate VAS sensitivity when exposed to the limitations of real-world data systems.

If a sufficient number of questions remain, a third phase of prototyping may be required. Potentially, this could be the vehicle for performing a detailed cost-benefit analysis. Alternatively, the operational prototype may yield enough information to provide financial justification of VAS. In either case, if VAS is deemed to offer a worthwhile return on investment, and if prototyping has otherwise been successful, the Army should begin to develop detailed specifications for full-scale implementation. The experience gained during prototyping will serve as a strong foundation for this effort.

¹Similar efforts have been undertaken in the past by the U.S. Air Force's Tactical Air Command. For example, see Capt J. F. Shambo, *An Evaluation of the Dyna-METRIC Computer Model Using Exercise Data*, Headquarters, Tactical Air Command, Langley Air Force Base, Virginia, July 1982; and Capt D. C. Pipp, "Coronet Warrior: A WRSK Flyout," *Air Force Journal of Logistics*, Summer 1988, Vol. 12, No. 3, pp. 1-4.

Appendix A

OVERVIEW OF THE VISION PROJECT

The goal of the Visibility of Support Options (VISION) project is to improve the combat sustainability of U.S. Army forces through the use of enhanced management information and decision support systems in the Class IX arena.¹

CENTRAL THEMES OF VISION

VISION features three recurrent themes. The first is the replacement of traditional measures of logistics performance (e.g., supply fill rate or manpower utilization efficiency) by measures that are more relevant to warfighting capability. Among these, weapon system availability has received the greatest attention and acceptance both in the Army and in the other services. Related measures, such as the attainability of planned weapon system activity levels in different combat postures, may also be worthy of examination.

Increasingly, the successful accomplishment of logistics missions depends upon the contributions of distinct—and often widely separated—organizations. As the level of interaction rises, effective coordination becomes more difficult. In recognition of this growing complexity, VISION's second theme is the integration of logistic activity across multiple functions and echelons in such a way that all participants work cooperatively toward the common goal of improved combat sustainability.

VISION's final theme underscores the importance of recognizing uncertainty and acting to overcome the disruptive effects of unanticipated events. An important consideration in this area is the availability of up-to-date information about the status of the logistics system and the projected needs of the combat force. Such data can be used to guide decisionmaking and the formulation of adaptive strategies.

¹The Arroyo Center's Military Logistics Program conducts similar research in the Class V (ammunition) area as well. See J. F. Schank, B. Leverich, and J. Paul, *Decision Support for the Wartime Theater Ammunition Distribution System: Research Accomplishments and Future Directions*, RAND, R-3794-A, June 1990.

COMPONENTS OF VISION

The VISION concept is formed around three primary elements: an assessment system (VAS) to assist the sustainment planning process, an execution system (renamed by the Army and now known as the Readiness-Based Maintenance System, or RBMS) to guide maintenance and distribution decisionmaking, and a command and control (C2) system to provide the necessary links between the planning and execution functions as well as between the operations and logistics communities.² Figure A.1 illustrates the relationships among the three VISION components.

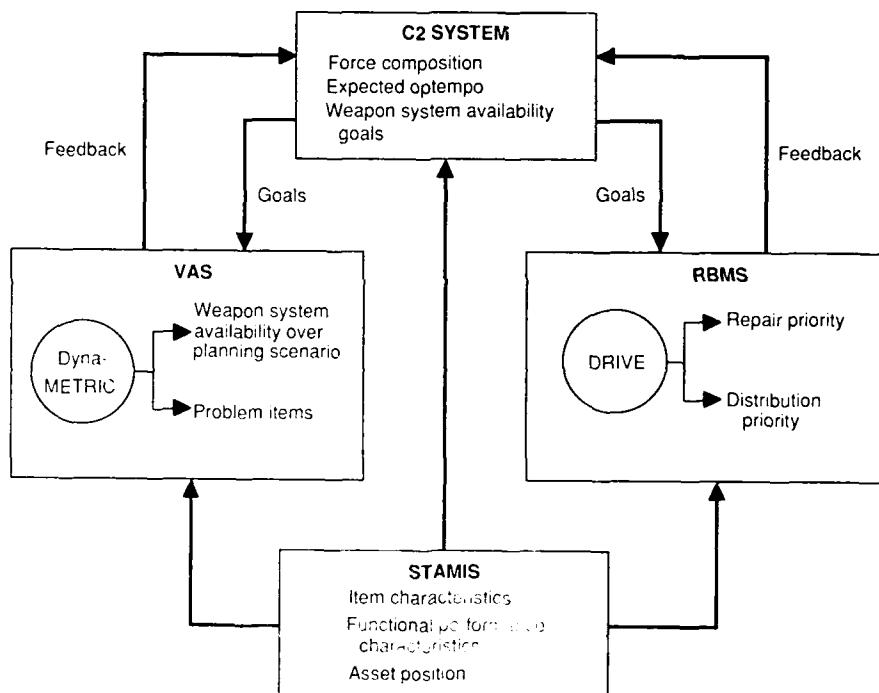


Fig. A.1—An Integrated View of VISION C2, Assessment, and Execution Systems

² VAS is the subject of the present report. RBMS is described in R-3702-A. The C2 system will be described in the third of the VISION series of concept papers.

The VISION C2 System

At present, the VISION concept of C2 is narrowly defined to include the translation of operational plans and goals into logistic needs, the transfer of that information to VAS and RBMS, and the exchange of outputs among different VAS and RBMS modules.³

Operational plans and goals are defined in terms of several parameters. Force composition identifies the size, organizational structure, and weapon systems of the combat units being supported. It may vary over the course of the planning scenario as units arrive and withdraw, or as forces are lost during combat.

Optempo (or, alternatively, combat posture) defines the expected intensity of operations of the supported combat force. Like many other logistics models, the Dyna-METRIC and DRIVE models found in VAS and RBMS assume that demands for spare parts are generated in proportion to optempo. Optempo may be measured in terms of operating hours, miles driven, rounds fired, and so forth. It may be necessary for the C2 system to derive such factors from a qualitative statement of the commander's guidance (e.g., "Task force 1 advances to seize position A, task force 2 provides screening on the left flank, and task force 3 is held in reserve.").

Operational goals should also reflect the commander's guidance and the requirements of the operation plan. They should be stated in terms of weapon system availability levels to be achieved. These goals may vary across the elements of a combat force. In the example above, for instance, task force 1 may require 95 percent availability of its M1 tanks, whereas task force 3 requires only 60 percent availability. The specification of goals may be unilateral on the part of operations planners or it may reflect an iterative process in which availability rates are projected via VAS, evaluated by operations planners, and, if found to be unsatisfactory, reassessed in view of potential changes in support plans.

The VISION Assessment System

VAS is intended to be an integral part of the sustainment planning function. It allows planners at all levels to project weapon system availability over the course of a given operational scenario. It uses a logistics assessment model (Dyna-METRIC) first to compute the ex-

³Eventually, the C2 function may be broadened to provide for information transfer relating to other aspects of logistic support. Possibly, the VISION C2 system could be embedded in larger Army management systems, such as the CSSCS module of ATCCS.

pected demands for logistic support arising from an operation plan, and then to evaluate the adequacy of logistic resources and functions (e.g., supply, maintenance, and transportation) for meeting those demands. In the course of performing this evaluation, VAS also identifies particular items and functions that are most likely to limit weapon system availability. The ability of VAS to represent a wide range of alternative support policies allows it to be used in determining "get well" plans in the event that projected performance falls short of operational requirements.

The outputs of VAS have two purposes. First, the projection of weapon system availability over time allows logistics planners to quantify the supportability of alternative operation plans. Projected availability may be compared with stated goals or, alternatively, it may be used to help establish the goals to be passed to RBMS. The second purpose is to identify the need for specific actions to improve projected performance. Such actions may include cross-leveling of spares among different units, sharing of repair resources, or longer-term modification of support structures and policies. In some cases, they may impose special requirements upon RBMS; if so, those requirements may be passed via the C2 system.

The Readiness-Based Maintenance System

RBMS provides real-time decision support to maintenance and distribution managers at all levels in the logistics system. It uses a prioritization algorithm (DRIVE) to orchestrate actions (which item to fix next and where to send it when it is fixed) on the basis of stated weapon system availability goals and operation plans. RBMS operates over short time horizons (ideally, no more than a few days) to retain maximum flexibility and responsiveness in the face of uncertainty. Thus, should there be significant departures from the anticipated course of events, it can react quickly to establish new priorities.

VISION EXPLOITATION OF ADVANCED INFORMATION SYSTEMS

In addition to the operational plans and goals furnished via the C2 system, VAS and RBMS rely upon accurate, timely data about the status of the logistics system. Much of this can be provided by existing or evolving STAMISes. Logistic data include descriptions of item characteristics (demand rates, indenture structure, repair times, etc.), asset positions (where items are held, in what quantity, and in what condition), and functional capabilities (e.g., repair capacities and

transportation times). Such data may be drawn from local sources by VAS or RBMS modules, or they may be fed into the C2 system for transfer to other locations as needed.

Appendix B

OVERVIEW OF DYNAMETRIC

VAS needs a highly capable assessment model to determine the extent to which operation plans can be supported with existing resources. This need is filled by the Dyna-METRIC model.¹ This appendix explains the origins of Dyna-METRIC, its uses, the differences between model versions, and its principal characteristics.

ORIGINS OF DYNAMETRIC

RAND developed Dyna-METRIC under Air Force sponsorship in 1980 to facilitate the quantitative analysis of logistics support policy for theater tactical air forces. As the model evolved in succeeding years, so too did its range of application. As early as 1984, the Army's Concepts Analysis Agency (CAA) evaluated Dyna-METRIC's structure and capabilities in the context of a wartime helicopter sustainability study. CAA's findings indicated that Dyna-METRIC was in many ways better suited to conducting detailed, large-scale assessments of logistic support than were other models in use at the time (extended PARCOM, Overview, etc.).² Since then, Dyna-METRIC has undergone further modification and upgrading; several extensions improved the representation of Army logistics structures for both aircraft and ground forces. Newer versions of the model have supported research efforts both in RAND's Arroyo Center and in the Army.³

The technical, policy-analytic, and user-oriented aspects of Dyna-METRIC are discussed at length in a separate series of RAND docu-

¹For Dynamic Multi-Echelon Technique for Recoverable Item Control.

²T. A. Rose, *Test of the Dyna-METRIC Aircraft Readiness and Sustainability Assessment Model*, U.S. Army Concepts Analysis Agency, Bethesda, Maryland, CAA-TP-84-12, November 1984.

³Arroyo Center work, conducted as part of the "Alternative Structures" project, is described in R-3673-A and R-3678-A. The Army's TRADOC Analysis Command used Dyna-METRIC to study the need for advanced test equipment; that work is reported in J. L. Noble, *Intermediate Forward Test Equipment (IFTE) Cost and Operational Effectiveness Analysis (COEA)*, U.S. Army TRADOC Analysis Command, White Sands Missile Range, New Mexico, TRAC-WSMR-COEA-6-89, January 1989.

ments.⁴ This section highlights the model's key attributes, including its data requirements and principal output products.

USES OF DYNAMETRIC

Dyna-METRIC supports both logistics capability assessment and spare parts requirements estimation. In the former role, it projects weapon system availability for a combat force over time and as a function of operational activity (which is assumed to drive the demand for parts), supply levels, and the performance of other elements of the logistics system (e.g., maintenance, transportation, and procurement). In conjunction with such projections, it also identifies any parts that are likely to obstruct the attainment of overall weapon system availability goals. These abilities make Dyna-METRIC the ideal tool for carrying out the planning/assessment tasks addressed by VAS. Moreover, the model's flexibility in representing the quantity and quality of logistic resources makes it especially well suited for performing the "what if" analyses that are an important adjunct to overcoming many difficult planning problems.

In its requirements estimation mode, Dyna-METRIC computes the least costly mix of spares needed to preserve a specified level of weapon system availability in a combat force operating at a specified level of activity. Requirements estimation embodies the reverse of the "resources-to-performance" orientation of capability assessment, in that it begins with a performance standard and projects backward to arrive at a necessary package of resources. Used in this way, Dyna-METRIC can help to clarify the objectives of problem-solving strategies. In addition, it can assist planners in tailoring basic loads for a broad spectrum of forces and missions.

⁴The underlying mathematics for the initial versions of Dyna-METRIC are outlined in R. J. Hillestad and M. J. Carrillo, *Models and Techniques for Recoverable Item Stockage When Demand and the Repair Process Are Nonstationary—Part I: Performance Measurement*, RAND, N-1482-AF, May 1980. The shaping of those mathematics into a formal model is described in R. J. Hillestad, *Dyna-METRIC: Dynamic Multi-Echelon Technique for Recoverable Item Control*, RAND, R-2785-AF, July 1982. Dyna-METRIC's capabilities and its potential as a tool for logistics policy analysis are discussed in nontechnical terms in R. Pyles, *The Dyna-METRIC Readiness Assessment Model: Motivation, Capabilities, and Use*, RAND, R-2886-AF, July 1984. The introduction of several new features and the transition from a theater-level to a global perspective are treated in R-3389-AF. More recently, the development of a simulation version of Dyna-METRIC with greater attention to the effects of uncertainty and management adaptation is described in R-3612-AF.

A NOTE ON MODEL VERSIONS

The wide variety of studies in which Dyna-METRIC has played a part over time has led to numerous enhancements, each intended to improve the model's treatment of a different aspect of logistic support. Although these changes have occasionally been dramatic, the underlying structure and purpose of the model have largely remained the same. At present, Dyna-METRIC exists both as a stochastic analytical model and as a Monte Carlo simulation.

Like its predecessors, the most recent analytical version of Dyna-METRIC (henceforth referred to as "Version 4") is based upon a dynamic extension of Palm's Theorem.⁵ Version 4 represents the logistics system as a network of *pipelines* that connect different echelons as well as the individual functions (supply, maintenance, etc.) within each echelon. Weapon system components are modeled as flowing through these pipelines in various stages of processing.⁶ Pipeline contents are computed as probability distributions whose chief parameters are component demand rates and process durations. At any point in time, the total pipeline contents for each component determine its supply status. The totals across all components are combined probabilistically to yield an overall measure of weapon system availability.

In the past three or four years, uncertainty and management adaptation have increasingly been recognized as constituting an important dimension of logistic support. To advance the understanding of their effects, a new version of Dyna-METRIC ("Version 5") was developed. However, the peculiar features of the problem invalidated much of the model's original mathematical foundations. In consequence, Version 5 was designed as a simulation. It retains the same structural view of the logistics system, but discards analytical methods in favor of a Monte Carlo sampling technique. The concept of component pipelines remains unchanged in Version 5, but rather than computing pipeline contents as exact probability distributions, the model generates them randomly over a large number of trials. Weapon system availability is observed directly in each trial, and its value then becomes subject to statistical analysis.

⁵This key result is demonstrated in G. B. Crawford, *Palm's Theorem for Nonstationary Processes*, RAND, R-2750-RC, October 1981.

⁶For example, components may be serviceable, in repair, awaiting parts needed to complete repair, on order from a higher echelon, or in transit between two locations. The time required to pass through a particular pipeline is determined by the duration of the process which that pipeline represents.

Individual organizations may wish to use different versions of Dyna-METRIC for the analysis of specific situations. VAS variations/modules can be structured to allow users to employ the version most appropriate to their needs. For instance, a division may prefer the greater speed and simplicity of Version 4 in assessing near-term operation plans. A theater, on the other hand, may need to use Version 5 to capture the greater uncertainty surrounding more distant scenarios. Whether all variations/modules should have both versions remains a topic for further research.

Much of the subsequent discussion of model characteristics applies equally to Version 4 and Version 5. Areas in which either one offers significantly greater capability than the other will be carefully noted.

CHARACTERISTICS OF DYNAMETRIC

Dyna-METRIC is not only well suited to the tasks required of VAS, but its design principles are in close accord with the basic themes of VISION. Several important examples of this parallelism are given below.

Representation of Large, Complex Structures

With the advent of Version 4, Dyna-METRIC acquired the capacity for examining worldwide logistics structures rather than just those within a single theater of operations. The model is able to fully depict the logistic activities and interactions of as many as four echelons of primary interest (for example, DS, GS, theater-based SRAs, and CONUS depots) with a somewhat less detailed view of two additional echelons (organizational and contractor, perhaps).

From a modeling standpoint, echelons possess no "hard-wired" features that distinguish one from another. Specification of the particular characteristics of each echelon and the relationships among all echelons is deliberately left to the user to allow a maximum degree of analytic flexibility. Thus, in a theater-oriented study, the user may choose to focus upon the organizational, DS, GS, and theater echelons, with CONUS depots represented more abstractly. Likewise, in a study of high-tech component support in which GS plays no major role, the emphasis may be upon DS (at brigade level), DS (at division level), theater SRAs, and CONUS depots.

In addition to accommodating a wide range of structures, Dyna-METRIC can account for different sets of interechelon linkages. For instance, the user may select a DS-GS-depot support chain for one

component and a simpler DS-depot chain for another. Dyna-METRIC's ready adaptability to alternative configurations and support concepts recommends it as a tool for structural planning and design, especially at higher levels of management. It also fits well with VISION's commitment to addressing the problem of integration and coordination across echelons.

Dyna-METRIC's multi-echelon outlook is complemented by its multi-indenture view of weapon systems. Weapon systems are modeled as aggregations of components (LRUs), which in turn are aggregations of indentured subcomponents (SRUs). Version 4 goes one step further, allowing the inclusion of sub-subcomponents (sub-SRUs, often "bit and piece" consumable items). Echelon-dependent differences between LRUs and SRUs (and sub-SRUs) may be reflected in such factors as their level of repair; for instance, LRUs may be declared repairable at DS whereas SRUs must be returned to the depot. Again, there is considerable room for the user to explore alternative concepts.

Operational Perspective

Dyna-METRIC was one of the earliest logistics models to lend substance to the view that the logistics system exists to support the needs of the combat force and should therefore be judged on the basis of its contributions to combat capability. Customary measures of logistics performance (e.g., supply fill rate, repair shop flow time, and order-and-ship time) are often correlated with combat capability but clearly fall short as ultimate indicators. Dyna-METRIC attempts to move closer by focusing upon weapon system availability—a superior measure of operational effectiveness. This perspective allows it to more easily bridge the gap between combat planning and logistics planning and thereby to accomplish the objectives of VAS.

Attention to Wartime Issues

Dyna-METRIC's mathematical underpinnings enabled it to be among the first logistics models to move beyond a steady-state, peacetime-oriented view of logistic support. It accounts explicitly for such dynamic, combat-related phenomena as sudden and dramatic surges and dropoffs in operational activity, phased deployment of combat forces and support resources, time-varying levels of force attrition and battle damage, and temporary (or permanent) cutoffs of repair and transportation linkages. Its capacity for recognizing and dealing with

such factors enhances Dyna-METRIC's relevance to both deliberate and time-sensitive planning and assessment of wartime scenarios.

Representation of Uncertainty

Logistics planning is hampered by uncertainty arising from many sources. Both versions of Dyna-METRIC attempt to account for that uncertainty, with Version 5 holding an advantage in terms of the number of sources portrayed and the detail with which their effects are represented.

Variability of component demand rates is a major source of uncertainty in both peacetime and wartime. It is reflected in both versions of Dyna-METRIC by adjusting the user-specified VTMR of the underlying probability distribution. In past practice, analysts often used the VTMR as a general-purpose parameter to "dial in" levels of uncertainty attributable to sources that were not explicitly depicted in the model. The usual setting for this approach was a wartime scenario in which the generally greater uncertainty of wartime could presumably be captured by selecting VTMR values substantially in excess of those corresponding to peacetime levels of demand rate variability.

Operational uncertainty impinges upon the logistics system to the extent that it affects the demand for spares and other types of support. Significant departures from formal planning scenarios, for instance, can lead to unexpected "peaks and valleys" in demand. This type of uncertainty may be represented in Version 4 by adjusting the VTMR in the manner described above. Version 5, on the other hand, is able to account explicitly for random variation in force composition and optempo.

Capacity constraints in resources such as maintenance and transportation also contribute a great deal of uncertainty. Such constraints are not always apparent in peacetime, but the combined factors of heavier loading and the possibility of resource damage or disruption increase the likelihood that they will occur in wartime. Version 4 contains a simple submodel of constrained maintenance that captures some uncertainty effects but can seriously underestimate the level of uncertainty when a particular set of loading conditions applies. Version 5 incorporates a considerably more detailed and robust submodel of the maintenance process. At present, neither version addresses constrained transportation; however, extensions in this direction are planned for Version 5.

Representation of Adaptive Strategies

The notions of uncertainty and adaptive strategies go hand in hand. Often, the only feasible methods for dealing effectively with unanticipated events require adaptations in resource management policies and practices. As is the case in their treatment of uncertainty, both versions of Dyna-METRIC contain a selection of adaptive strategies, with Version 5 exceeding Version 4 in both quantity and attention to detail.

Controlled exchange of components (usually LRUs) in short supply is a common device for minimizing the number of NFMC weapon systems at the organizational level. Similarly, SRUs and other repair parts may be switched among LRUs in DS, GS, and depot maintenance facilities. Cannibalization from badly damaged weapon systems is another accepted strategy for overcoming shortages. Both versions of Dyna-METRIC allow controlled exchange and cannibalization to occur at the user's option.

The potential for capacity constraints in maintenance and transportation suggests the value of prioritization as an adaptive strategy. As part of its constrained maintenance submodel, Version 4 offers priority rules ranging from first come, first served to an availability-driven rule that assigns the highest priority to the component that is currently deadlining the greatest number of weapon systems. Version 5 supports the same rules, plus a variation of the DRIVE algorithm that is embedded in RBMS. In addition, it allows distribution of serviceable assets to be prioritized by combat unit. As the constrained transportation submodel for Version 5 evolves, equivalent rules for transportation priority will be developed.

Mutual support is another promising strategy for overcoming the effects of uncertainty during intense, dynamic operations. For example, both versions of Dyna-METRIC permit maintenance workload to overflow to backup facilities (as from an overloaded brigade-level forward support battalion (FSB) to its divisional main support battalion (MSB)). Similarly, they allow parallel units to provide maintenance support to each other (as between two neighboring MSBs). Cross-leveeling (sharing of spares between units) is also represented; Version 4 accomplishes it by roundabout means that require one of its four echelons to serve an artificial function, whereas Version 5 employs a more direct approach.

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